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CDG

WASTE DISPOSAL AND RESOURCES RECOVERY

Proceedings of the
Seminar on Solid Waste Management
Bangkok, Thailand
September 25 - 30, 1978

Edited by

N.C. THANH
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Sponsored by
Asian Institute of Technology
Carl Duisberg Gesellschaft, e.V.
with the collaboration of
Environmental Resources Limited, London, U.K.

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FOREWORD

The intention of editing and publishing the proceedings of this first joint AIT/CDG-seminar finally ripened during the course of the last days of September 1978 when the regional seminar on Solid Waste Management was still going on at the Asian Institute of Technology, Bangkok, Thailand.

This seminar was the first of its kind in the field of environmental engineering and management as a promotional measure within the framework of the development policy of the Federal Republic of Germany. It was initiated, administered and sponsored by the Carl Duisberg Gesellschaft, Cologne, on befalf of the Federal Ministry of Economic Co-operation, Bonn. The Asia section of CDG planned, organised, and carried out the seminar as a joint venture together with the Environmental Engineering Division of the Asian Institute of Technology, Bangkok, the Waste Management Department of the German Federal Environment Agency, Berlin, and the Environmental Resources Limited, London.

The seminar, especially designed for waste management planners and senior engineers, was attended by 32 participants from 8 Southeast and East Asian countries: Hong Kong, Indonesia, Korea, Malaysia, Philippines, Singapore, Taiwan and Thailand. Its main objectives were as follows: Firstly, to enable the participants to gain a deeper understanding of alternative techniques and methods available for waste management planning as well as enabling them to take decisions relating to the safe and economic collection, transport, handling, treatment and ultimate disposal of waste arisings from consumer, trade and also industrial sources. Secondly, to assimilate and edit the particular experiences of problems encountered with waste management and resource recovery in Asia while highlighting the specific conditions prevalent in the respective areas of mass urbanisation and industrialsation in the Far East and Southeast Asia: the nature of waste, climate and hygiene, the influence of geographical factors, living standards, economics, political administration, cultural and social environment etc. Thirdly, to encourage the free and open exchange of industrial experience in waste management and resource recycling between specialists of a participating country in the respective Asian region as well as between Asian and Western European experts.

For the aforesaid reasons the content of the lectures and the numerous bilateral and group professional discussions centered around the following topics:

- Operational factors and economic analysis in waste management planning and decision-making.

- Alternative technologies for collection, transport, handling and treatment of urban and industrial waste

- Regional problems of solid waste management in the majority of developing countries in Asia, e.g. densely-populated areas, lack of funds, equipment and trained manpower, differing climatic conditions, high moisture content of refuse, etc.

Of particular importance for the organiser, however, was to stress 2 points:

1) The main purpose of this basically not-only-academic seminar was to obtain data, information and experience of practical relevance; i.e. it was essential that it will be assimilated by professionals for professionals. Its components should serve as an operational guideline for participating Asian specialists in their search for rational solutions to their own particular waste management problems in order that they manage their tremendous tasks more efficiently, effectively and economically and - at the same time - take into account the given local restrictions with the aim of trying to reduce environmental damage and danger, at least by a step-by-step programme.

2) An integral part of the seminar concept was to promote mutual professional as well as personal understanding and learning, above all between the participants from the different Asian nations; additionally between the participants, lecturers, organisers and also between the parties involved on the organising side: AIT, ERL, UBA and CDG.

Although of only indirect relevance to seminar participants, it should be noted that the initiator intended to attain 2 further goals by way of this solid waste management seminar:

1) Initiating joint AIT/CDG seminar activities in order to broaden the scope of common understanding thereby strengthening the co-operation and partnership between both organisations: the Asian Institute of Technology and the Carl Duisberg-Gesellschaft.

2) To establish a pilot seminar in order to introduce and establish the field of environmental technology and management as a new area for activities of further training under the German educational aid policy.

Some participants showed their curiosity about the fact that the German Government sponsored and engaged itself through the CDG in the field of further training for environmental technologists and planners in general and in solid waste management in particular. But I could respond that there was no secret behind this engagement.

This seminar could take place in Asia in 1978 because of my own personal interest in environmental problems and therefore my belief that this important field should no longer be neglected in the scope of our training and educational aid activities, and the fact that my regular work deals with and is confined to the Asian region.

At the end of the seminar the participants were asked to complete a questionnaire in order to help us to assess its results. Overall, the participants' comments were very complimentary about the seminar. In particular they praised the selection of subjects, the efficiency of the organisation and the material that had been provided.

The overall impression was that the participants found the seminar to be extremely valuable and this was reinforced by numerous comments received during the course of the seminar. Almost all participants agreed that the most interesting and challenging aspect was the case study work. In addition, many said that they were now in a better position to take rational decisions and to question certain decisions that had already been taken. Whereas the first 2 groups of questions referred to the direct evaluation of the seminar, the third referred to subjects which may be covered by a follow-up seminar and the last placed emphasis on the participants' experience on the types of training programmes required. The answers showed that there is a great demand for mainly practical training courses for professionals with operating experience; particularly for advanced training on technical processes.

The next solid waste management seminar in December this year will reflect the responses of the previous one and will concentrate more on the problems and circumstances faced by solid waste managers, decision-makers and planners in the participating Asian countries. An overall case study with 4 subcase studies will be grouped to serve as medium in order to evaluate in detail the data requirements, the technical options and their constraints, and the analysis of economic, social and environmental factors which form the essential components of a waste-management-master-plan. Particular reference will be given to energy economics which will play an even more crucial role in future developments.

I do hope that these proceedings shall reach a much larger audience than a week-long seminar might accomplish in order to also serve many other waste management professionals, for example as reference material and perhaps guidelines for daily work routine. It might be helpful for environmental administrators with a planning and overall decision responsibility at a regional or central government level as well as for those with an operational responsibility in this field: directors and senior staff of solid waste organisations.

Finally, I acknowledge with gratitude, the positive role and the remarkable flexibility of the responsible sections of the Federal Ministry of Economic Co-operation and the relative liberality of the

CDG's organisational structure. I am very grateful to the joining Asian partner organisation: The Environmental Engineering Division of the Asian Institute of Technology whose faculty and staff had done everything to make the seminar not only a successful venture but also personally a very pleasant event. Their warm hospitality will not be forgotten. I must also thank our European partners: The German Federal Environment Agency, Berlin, and the Environmental Resources Limited, London, for their considerable input prior to and during the seminar. Above all, I was very much impressed by the enthusiasm with which the participants approached the course. Their clear interest in taking part at every stage was an essential component for the good outcome of the seminar. This was only made possible through the joint efforts of all parties concerned. I express my sincere thanks therefore, to each individual participant.

GÜNTER THARUN

Regional Director for Asia, CDG
Cologne, May 1979

PREFACE

The problems associated with the management of solid wastes in today's society are complex because of the quantity and diverse nature of the wastes, the development of sprawling urban areas, the funding limitations for public services in many large cities and the impacts of technology. If solid waste management is to be accomplished in an efficient and orderly manner, the waste collection and disposal systems chosen must be most appropriate for the local conditions and operated in an optimum way, the fundamental aspects and relationships involved must be identified and understood clearly. Public attitude and concerns are to be regarded as crucial for the process of sanitation education of all members and social categories of a community at all age levels.

This seminar has been organised by AIT's Environmental Engineering Division with the financial assistance of Carl Duisberg Gesellschaft, e.V., on behalf of the Federal Ministry of Economic Co-operation, Bonn. The Proceedings, divided into two parts contain 25 papers and one case study.

Part I includes a Case Study and all the state-of-the-art reports presented by the lecturers from the Asian Institute of Technology, the German Federal Environmental Agency and the Environmental Resources Limited, U.K. covering various aspects of solid waste management in Asia and abroad. Part II exclusively presents the selected papers of the participants who attended the seminar. The participants' papers had to be edited without altering the opinions presented by the authors. Finally, the proceedings provides a list of the invited participants and lecturers who worked towards the success of the conference.

We gratefully acknowledge the financial support of Carl Duisberg Gesellschaft, e.V., Cologne without which the seminar would have not been possible. The participation of the Waste Management Department of the German Federal Environment Agency (Umweltbundesamt, UBA), Berlin and the colloboration of Environmental Resources Limited, London are highly appreciated.

Many people have contributed to the development of the proceedings. Their help is acknowledged gratefully. The faculty, students and staff of the Environmental Engineering Division provided valuable support for this endeavour. Punnee and Ratana typed the final manuscript Sakda helped prepare the figures. To Tony Waltham who served as assistant editor, we appreciate his professional service. We wish to thank all the members of the organising committee and AIT community for their assistance in making this seminar a success. Finally, to Khun Pitak who advised on many aspects regarding the publishing work, we owe much gratitude.

N.C. THANH
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PART I

STATE–OF–THE–ART LECTURES

SPECIFIC PROBLEMS OF SOLID WASTE MANAGEMENT IN ASIA

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INTRODUCTION

The inability to evaluate the status of the art of solid waste disposal and to develop logical and economical systems to meet the everchanging circumstances is probably the most serious shortcoming in the field of public works. This can be attributed to the very nature and origin of the problem: waste disposal has historically been relegated to the lowest levels of responsibility.

Many changes have been taking place. The character of the wastes has changed in line with rising standards of living, retail distribution methods and fuel technology. The volume has increased; storage methods have evolved from open heaps through portable and disposable containers; transport has improved from horses to motor vehicles and from open trucks to compactor vehicles. The advent of high-rise buildings, supermarkets, institutions, hospitals and industries have given rise to new problems and efficient solutions have been devised.

Industrialised countries can usually cope with these problems. Basic health and environmental problems have been solved although some problems of resource recovery and disposal still remain. An efficient taxation system generates sufficient money to provide an efficient public service. The technology of waste handling is now highly developed, the production of equipment has increased and technical training institutions have been organised.

However, many countries in Asia are suffering the impact of urbanisation. Population densities are higher than any developed country but Asia does not have the financial resources needed to provide equivalent solutions. The quality of the urban environment is a matter of growing concern and the importance of efficient solid waste management is increasingly being recognised.

COLLECTION AND DISPOSAL METHODS

In most countries in Asia, communal storage is being practised. This method includes the use of uniform and non-uniform portable bins with lids, large fixed bins made of steel, concrete, bricks, iron sheets or wood. Open street dumps are also common. Frequency of collection may vary from 3 times a week to twice daily. Large open motor vehicles are commonly used although bullock carts and handcarts are used to collect from inaccessible areas.

Street sweeping is normally manual, except in very few countries like Singapore, where they use mechanical sweepers. The type of brooms used is usually of coconut fibre which varies from short, flexible, hard brushes to stiff brooms with long handles. Primary transport of sweeping in these cities includes baskets, wheelbarrows, bin trucks, bullock carts and handcarts.

About 90 per cent of the waste in Asia is disposed of by crude dumping, although sanitary landfilling or controlled tipping is being practised to some extent in Korea, Singapore, Taiwan and Hong Kong.

Non-mechanised or manual composting is successfully operated in India but is rare elsewhere. In Taiwan, provincial governments have erected semi-mechanical refuse composting treatment plants and a mechanised composting plant is also being operated in Bangkok. All these are not commercially successful because much of the product remains unsold.

Few incinerators operate in the region and to a very limited extent. An incinerator is being operated in Sri Lanka mainly for the destruction of foodstuff condemned as unfit for human consumption and disposal of animal carcasses. Although incineration remains the preferred method of refuse treatment in Hong Kong, visibility and atmospheric pollution raise some objections. A small incinerator plant in the Philippines is at present non-operational due to its high operating cost.

Labour-intensive recycling operates on a vast scale. Householders have newspapers, tin cans, scrap metals, plastics recovered and sell them. At every stage of storage, collection and disposal, saleable items are salvaged so that recovery is negligible when the wastes reach the disposal site.

SPECIFIC WASTE MANAGEMENT PROBLEM

Water Pollution

Leachate from dumps, static water in dump sites, the use of streams and canals for solid waste disposal and decomposition of solid wastes are potential sources of water pollution. Water drainage systems are frequently impaired due to blockage of ditches, gullies and sometimes major waterways by solid wastes.

Obnoxious Odours and Air Pollution

Open communal storages and dump sites and open collection trucks produce obnoxious odours and wastes and litter are accidentally blown out into the streets or scattered by stray dogs and animals and illegal scavengers. Temporary storage, burning of refuse at street corners and roadsides also causes air pollution.

Rodents and Insect Vectors

The very large numbers of open communal storage and unofficial dump sites, together with the universal failure to cover landfills properly, encourages the breeding of flies and rodents.

Direct Health Hazards

Aside from the health risk brought about by these insect vectors, the methods of collection allow workers to be exposed directly by regular skin contact with wastes which sometimes contain fecal matter and offensive materials. This accounts for the increased incidence of certain diseases and accidents among refuse collectors.

Lack of Motor Vehicles and Equipment

Almost everywhere in Asia, motorised collection vehicles are not only too old but too few in number. Poor maintenance and the lack of a vehicle replacement policy aggravates the problem. A considerable amount of equipment used is no longer in good working condition. In most cities, except Singapore, regular checkups of the vehicles and spare parts replacement are ignored or not considered seriously due to lack of funds.

Delayed and Inefficient Refuse Collection

Improper scheduling of collection vehicles causes delays in collection. There are times when the collections are held up for such a long time that households have to dispose of their wastes in their backyards, vacant lots or sometimes into streams or canals. Often, garbage collectors are too careless in transferring refuse from the containers to the dump trucks causing the scattering of litter and refuse on the streets.

Dense Traffic

In most large cities in Asia, the work of collection vehicles is impeded by dense traffic. Road congestion and street obstructions caused by the increasing number of roadside parked cars is the most notable problem in Singapore where mechanised street cleaners are being used. This problem is somewhat minimised by the collection of refuse at night or dawn.

Narrow Streets and Alleys

Handcarts, rickshaws, bullock carts or baskets are used to collect refuse in some old parts of cities and towns where streets are too narrow to admit large motor vehicles. However, it is very common for some of these alleys to be just ignored and denied collection, causing an accumulation of rotten refuse and wastes in yards or on the banks of streams and ditches. This is an eyesore and emits foul odours.

Land for Waste Disposal

Almost everywhere, finding suitable landfill sites is a problem for governments due to the unavailability of and the high cost involved in acquiring the land. Often the landfill sites are outside the city in which transfer and transport of collected refuse add to the cost of operation. In Dacca and Rangoon which maintain a small fleet of collection vehicles, no vehicle could be spared for any other additional work.

Accidental Fires and Gas Leaks

Accidental fire at a landfill is not surprising and may arise due to several causes : a lighted cigarette thrown down by a careless worker, hot ashes in a vehicle delivering waste, the sun's rays through a fragment of glass. Fires have often been seen on the surface of landfills in most Asian countries due to high density, high vegetable components of the waste unlike in Europe where serious underground fires have caused the collapse of the surface into voids caused by fire. Toxic gases like carbon monoxide, carbon dioxide, methane and hydrogen sulphide are produced as a result of decomposition. These gases produce an extremely offensive odour which at a certain concentrations may cause unconsciousness.

Dust

In countries where controlled tipping or sanitary landfilling is practised, the process of excavation, hauling and placing of earth cover materials, under dry weather conditions, presents a major dust problem. In Singapore where there is an extensive silting of roads caused by earth littering from constructional activities, the sweeping of heavily-silted areas by the use of the mechanised sweeping units generates dust and occasionally causes accidents as a result of dust obliteration.

Lack of Co-operation from the Public

Public dissatisfaction with cleansing standards is often aired through the radio, press, letters and other media in the same way that most government officials complain of the lack of co-operation from the public. It is evident that services have not reached that stage which commands public respect and co-operation, with the exception of Singapore, where more stringent laws and regulations are enforced and people are quite satisfied with the services that they are getting.

CONSTRAINTS TO SOLUTIONS OF THE PROBLEMS

Solutions to these various problems are also subject to a number of constraints and these are some of the reasons why methods generally practised in Western countries are not suited to or adopted in Asia.

Climate and Weather Conditions

A common denominator to all collection systems is climate and weather conditions. Heavy rains increase leachate problems and run-off causing surface water pollution. Accumulation of waste causes blockage of ditches, streams and canals after heavy rains and flooding which increases vehicular traffic all helps to hinder waste collection. Moisture content and the density of wastes vary with the season and thus impose problems on both collection and disposal methods. Wet weather impedes plant operations which result in higher maintenance costs and easier wear and tear.

Lack of Funds

The most pressing factor is the economic stability of the country, the availability of sufficient funds to enable the government to provide a good standard of service and the ability of the community to pay for such a good standard of service. Very often, solid waste problems are being ignored and given minimum priority both by the government and the public sectors. FLINTOFF (1976) reported that Europe spends about US$ 10/head/yr as compared with an average of about US$ 0.60 in most Asian cities, inspite of a greater total workload due to access problems, the need for daily collection, more complex housing and inefficient traffic systems.

Limited Foreign Exchange

Shortage of foreign exchange for most countries in Asia with the exception of Singapore, Hong Kong and Indonesia means the purchase of foreign equipment is often blocked as preference is given to such necessities as medicines, food and oil.

Social and Religious Factors

Although there is no well-founded information on these matters, some strict religions do not tolerate the storage of kitchen wastes in the house, and they must be removed from the premises immediately after each meal. The manner of rearing domestic animals somehow depends on certain social and religious norms. The social and religious attitude towards cleanliness plays an important role too.

Public Ignorance

The public is not well-informed and trained in the habits of cleanliness and sanitation both personal and public. Inadequate publicity on health hazards results in indiscriminate dumping and the throwing away of refuse. Because of this unawareness on the part of the people, co-operation cannot be fully expected from them.

COMPARATIVE DATA ON SOLID WASTE MANAGEMENT PRACTICES IN ASIA

Based on the data reported by FLINTOFF (1976) and the country reports on solid waste management (Refs: 2,4,5,6,7,8,9,10,11), Table 1 shows comparative data on solid waste. Some of the figures in Table 1 are estimates calculated from the different figure suggested and reported and are exclusively used here for comparative purposes. Rounded off, the following figures are as follows:

Waste production	-	250-870 g/head/day
waste collected	-	75-870 g/head/day
Density of waste	-	250-600 kg/m^3
Workers/1000 pop.	-	1-3
Wages/hour	-	5-20 US cents
Expenditure/year	-	25-150 US cents/person

A comparative refuse analyses for some countries in Asia has also been prepared and is shown in Table 2. Further comparative data are presented in Table 3 and Table 4.

Waste Production

The average amount of wastes produced from residential houses, shops, markets offices, institutions, cottage industries and street litter is about 350 g/head/day with variations of not more than 30 per cent with the exception of Jakarta where it may exceed 600 g, and in Hong Kong and Singapore where wastes produced may be comparable with that of some countries in Europe.

Waste Collection

Although Hong Kong and Singapore display an efficient collection system, a substantial proportion of wastes produced are still not collected in most countries. These uncollected wastes accumulate in backyards, roadsides, in rivers or canals, are scattered by stray animals or blown away by strong winds. The proportion of uncollected wastes is highest in Kathmandu and lowest in Singapore.

Character of Wastes

There are two factors that influence density : the character of the wastes and methods of storage and collection. Bangkok's wastes are characterised by their low density representing consumer society wastes, having a paper content of 25 per cent and collected directly from dwellings. Hong Kong's wastes have an even higher paper content

Table 1 Tentative Comparative Data on Solid Wastes.

	U.K.*	INDIA*		NEPAL*	BANGLADESH*		BURMA*	INDONESIA*	SRI LANKA*	THAILAND*	HONG KONG**	PHILIPPINES**	SINGAPORE**	TAIWAN**
City:	Typical	Bangalore	Delhi New Delhi	Kathmandu	Dacca	Chittagong	Rangoon	Jakarta	Colombo	Bangkok	Hong Kong	Manila	Singapore	Taiwan
Population		1,650,000	4,004,000	200,000	1,311,000	600,000	1,900,000	5,000,000	580,000	3,300,000	4,500,000	7,042,492	2,300,000	-
Population density/sq.km	4,000	12,750	8,640	1,070	19,600	7,229	3,482	8,375	15,500	11,350	12,975	11,240	3,840	470
Population max. density/sq.km	12,000	70,000	250,000	56,500	38,000	-	60,600	50,000	68,000	85,900	25,400	-	-	-
Ave. persons/dwelling	3	5	-	6	8-10	8	5-8	8	6	7	-	-	-	-
Production g/head/day	900	415[4]	-	250	350	280	250	604	420	455	850	500	870	400-500
Collected g/head/day	900	370	-	75	305	250	210[1]	404	400	303[1]	840	-	870	-
Density kg/m^3	150	570[1]	-	600	600	-	400	400	400	250[1]	-	-	175	-
Workers/2000 population	1.3	1.8	3.2	1.5	1.2	1.1	1.0	1.1[2]	2.8	1.2	-	1.67	0.5	-
Wages/hour US$	2.00	0.15	0.13	0.05	0.13	0.13	0.10	0.08	0.17	0.20	-	-	-	-
Kgms collected/worker/day	700	237	-	50	260	227	222	286	135	244	-	300	1,843	-
Diesel cost US$/litre	0.29	0.13	0.13	-	0.17	-	0.11	0.04	0.16	0.12	-	0.21	-	-
Petrol cost US$/litre	0.29	0.42	0.40	-	0.42	-	0.16	0.11	0.41	0.17	-	0.24	-	-
Annual Expenditure US$ head pop.	10.00	0.70	1.06	0.20	0.32	0.37	0.18	0.40[3]	1.53	0.55	-	-	-	-
GNP/head pop. US$	-	(1967)84	(1967) 84	(1968) 75	(1972) 60	(1972) 60	(1968) 78	(1968) 83	(1969)160	(1970) 187		(1977) 410	2,700	1,070

1 Based on complete records of weight or volume or reliable sampling.
2 Plus work by private collectors.
3 Plus payments to private collectors.
4 Average for all India 377 g/head/day (NEERI) National Environmental Engineering Research Institute.

* Solid Wastes Management Practices in Southeast Asia, SEA/EH/Wastes sem./W.P. 3, 27 Sept, 1974.
** Solid Wastes Management Seminar Country Reports, Bangkok, Thailand, 25 Sept - 30 Sept, 1978.

(Note: The reliability of these figures cannot be affirmed. They should be used only as approximations for purposes of comparison).

Table 2 Comparative Refuse Analysis

	Britain*	Bangkok*	Bangalore*	Bangalore*	Hong Kong[1]	Jakarta[1]	Seoul[1]	Taiwan[1]	Singapore[2/]
	Typical	Analysis by Municipality	Analysis by Flintoff Burner	Analysis by NEERI Summer					
Vegetable/putrescible	28	44.0	75.2	65.1	9.42	60	-	24.6	4.6%
Paper	37	24.6	1.5	2.7	32.46	2	4	7.5	43.1%
Metals	9	1.0	0.1	0.4	2.17	2	0.4	1.1	3.0%
Glass	9	1.0	0.2	0.2	9.72	2	0.15	2.8	1.3%
Textiles	3	3.0	3.1	0.9	9.58	-	-	3.7	9.3%
Plastics and Rubber	3	7.0	0.9	0.3 (exe.rubber)	6.24	2	1.8	2.3	6.1%
Misc. Combustatle	1	-	0.2	0.2	4.94	7 (egg Shells)	0.6 (Wood)	-	3.9%
Misc. Incombustable	1	3.5	6.9	1.2	-	-	78.0 (ashes)	56.0 (ashes)	-
Inert below 10 mm	9	4.8	12.0	-	14.09	-	-	-	6.4%
Fine Earth	-	-	-	29.0	-	-	-	-	-
Other Materials	-	-	-	-	10.47	25	13.7	0.8	22.3%
Density kg/m^3	150	250	570	405	-	-	-	-	175

Note : * - Solid Wastes Management Practises in Southeast Asia, Report by Frank Flintoff, WHO Consultant.

1 Country Reports on Solid Waste Management Seminar, Bangkok Thailand 25 Sept. - 30 Sept, 1978.

2 Personnel Communication

of about 32 per cent. Bangalore wastes have only 2 per cent paper, Seoul 4 per cent and Taiwan 8 per cent are more typical of the region as a whole. Seoul and Taiwan account for a significant high ash content of 57-78 per cent, which originates from hard coal which is used as domestic fuel and this amount may increase during winter. Generally the major constituent of the wastes is putrescible or fermentable organic matter which accounts for 35-75 per cent of the total.

Worker Performance

The normal performance of a worker in the region (total weight collected divided by total manual employees) is about 250 kg/day FLINTOFF (1976). Exceptions are Nepal, about 50 kg/day, Colombo about 135 kg/day and in Singapore with a very high worker performance of about 1,850 kg/day. The introduction of mechanisation in Singapore accounts for the decrease in the labourers' workload, maintaining their work productivity.

Number of Workers

Usually, it is necessary to employ 2 workers per 1,000 population to achieve reasonable standards. As reported by FLINTOFF (1976) although Rangoon employs only 1 worker/1,000 population, standards observed in the central area were very high. Due to the implementation of mechanical sweepers in Singapore, there is very significant decrease in the number of workers. However, the equivalent deployment ratio between men and a machine is in the region of 16:1.

Rates of Pay

The rate of pay for sweepers and collectors seems to be lower than other unskilled workers as exemplified in Kathmandu where the rate is so low that there is no incentive to work. Dacca employs only casual workers for 4 hours a day. However, most workers are permanent, working for 7 or 8 hours a day. In Manila, street sweepers and collectors even enjoy some fringe benefits in the form of life and accident insurance, uniforms and raincoats and incentive awards to deserving personnel.

Level of Expenditure

Annual expenditure on street cleansing, refuse collection and disposal per head of population was difficult to ascertain on a truly comparable basis as cited by FLINTOFF (1976) in his report. Although some budget figures are used it was necessary to calculate some costs from other data. Due to different financing schemes of vehicles, amortisation of vehicles and plants has been excluded. In Southeast Asia, the average figure is about US$ 0.60/head/year, although the range is very wide. Because of adequate staffing, well-designed plants and vehicles and district depots, Colombo reported an expenditure of US$ 1.53/head/year. No data was obtained from other countries like Singapore and Hong Kong where waste management is relatively efficient.

Table 3 Comparative Data on the Countries in Asia

	Bangladesh	Hong Kong	India	Indonesia	S. Korea
Population (000,000)[1]	83.3	4.5	622.7	136.9	36.4
Population Density/sq.mi (1977)[2]	1,447.9	10,918.0	490.2	246.4	958.9
Growth Rate[1]	2.7	1.4	2.1	2.4	1.7
Birth Rate[1] (per 1,000)	47.0	20.0	34.0	38.0	24.0
Death Rate[1] (per 1,000)	20.0	5.0	13.0	14.0	7.0
Age Structure: % under 15 years[1]	43%	31%	40%	44%	40%
15 years - 64 years[1]			56.7%		56.7%
GNP (US$/cap)[1]	100.0	2,080.0	150.0	180.0	1200
Religions[2]	Moslem - 80% Hindu - 13%		Hindu - 83% Moslem - 11%	Moslem - 89% Christian - 7%	Buddhist Christian Confucianist
Economic Conditions[2]	Rural economy with principal crops of rice, tea and jute	Trade centre; industries include shipbuilding textiles & electrical products	Agricultural and partial industrial economy	Agricultural; petroleum - principal mineral product	48% rural agricultural area
Incidence of Infectious Diseases (Cases and Deaths, 1975)[3]	Cholera - 5,062 Smallpox - 13,798	Tuberculosis of the Respiratory System - 8,548 Infectious Hepatitis - 1,804 Typhoid Fever - 548	Cholera - 24,275 Smallpox - 1,612	Cholera - 51,458 Cardiac Diseases and Cancer	
National Government Protection Agency					Ministry of Health and social Environmental Protection Centre
Particular Government Agency for SWM		Public Works Dept.			

1 - Asia Yearbook, 1978
2 - Information Please Almanac, Atlas and Yearbook, 1978, 32nd Edition
3 - Singapore Facts and Figures

Table 4 Summary of Problems, Constraints and Deficiencies in Solid Waste Management in Asia

PROBLEMS	Bangalore[1]	New Delhi[1]	Kathmandu[1]	Dacca[1]	Rangoon[1]	Jakarta[1]
Water Pollution	Static water and dump		River pollution from dumps	Surface water pollution from dumps		Pollution of streams & rivers & surface water at dump
Vectors	Street bins and dumps	Street bins and dumps	Courtyard street dumps and main dumps	Street dumps and main dump	Some street dumps and main dump	Random dump and main dump
Health risks to workers	Skin contact	Skin contact	Skin contact	Skin contact	Skin contact	Skin contact
Landfill sites available	Yes	Yes	Yes	Yes	Yes	?
Motor vehicles shortage	Yes, many old	Yes, many old	Very few	Very few	Yes	Yes
Dense traffic	In some areas	In some areas	No	Few	No	Yes
Narrow lanes	In some areas	In some areas	In central	In some areas	Not many	Yes
Lack of public co-operation	Yes	Yes	Yes	Yes	No	Yes & no
Constraints						
Shortage of local money	Yes	Yes	Yes	Yes	Budget underspent	Yes
Foreign exchange	Difficult	Difficult	Difficult	Difficult	Difficult	No problem
Climatic problems	No	No	No	Yes	No	No
Deficiencies						
Equipment	Short brooms, no sweeper trucks	Soft brooms, few sweepers' trucks	Short brooms, few sweeper trucks	Soft broom, no sweepers' trucks	Sweepers' barrows too small	Sweepers'barrows too small
Vehicles	Open and too high	Open and too high	Open	Open and too high	Covered but too high	Open, too high no tipping gear
Training facilities, technicians in SWM	None	None	None	None	None	None

1 - Solid Waste Management in Southeast Asia Report and Working Papers of a Regional Seminar, Bangkok, Thailand 29 October to 7 November 1974

Malaysia	Nepal	Philippines	Singapore	Sri Lanka	Taiwan	Thailand
12.6	13.2	44.3	2.3	14.1	16.6	44.4
99.8	241.5	379.9	10,221.2	574.4	1,194.8	221.0
2.8	2.3	2.7	1.3	2.0	1.8	2.4
35.0	43.0	35.0	18.0	28.0	23.0	35.0
7.0	20.0	8.0	5.0	8.0	5.0	11.0
45%	40%	43% 52.4%[5]	34%	39%	(1975)[4] 35.3% 61.2%	(1975)[4] 47.6% 49.5%[5]
844.0	124.0	370.0	2,648.0	150.0	1,040.0	350.0
Moslem Buddhist	Hindu - 89.4% Buddhist - 7.5%	Catholic - 87% Moslem - 4.4%	Moslem Christian	Buddhist - 67% Hindu - 18%	Confucianist principally Buddhist	Buddhist - 95% Moslem - 4%
-argest in producer -griculture includes imber, rubber and -alm oil	Agriculture includes rice, wheat and jute	Chiefly agricultural; copra, abaca and sugar-chief products	Trade centre; industries include shipbuilding and oil refining	Heavily dependent on food imports; tea is principal product	Essentially agricultural; food processing - major industry	Principal agricultural economy
Cholera - 52 (excl. Sabah and -arawak)	Cholera - 260 Smallpox - 95	Cholera - 695	Tuberculosis of the Respiratory System - 2,901 gonococcal infections - 2,750	Cholera - 1,517	(1976)[6] Typhoid and paratyphoid - 131 Diptheria - 23 Dysentery - 17	Malaria - 290,447 gonococcal infections - 143,863 Leprosy - 35,845
			Ministry of Environment[3]			National Environmental Board
	City Municipality	Refuse & Environmental Centre of Metro Manila Commission	Environmental Public[3] Health and Environmental Engineering Div.		National Health Authority	

4 - Taiwan Statistical Data Book, 1976
5 - World Health Statistics, Annual, 1977 Vol. II
6 - Statistical Yearbook of the Republic of China 1977

Colombo[1]	Bangkok[1]	Hong Kong[2]	Seoul[2]	Manila[2]	Singapore[2]	Taiwan[2]
Static water at one dump	Static water at main dump	Leachate from sanitary landfill	Static water at dump leachate from landfill	Static water at dump	Leachate from landfill	Leachate from landfill
Dumps	Dump	No problem	Dumps	Street bins and dumps	Bin centres on roadsides	?
Minimal	?	Minimal	Yes & no	Skin contact	Minimal	Skin contact
Yes	Yes	No	Yes & no	Yes	No	No
Yes	Yes	No	No	Yes, many old	No problem	Yes
In some areas	Yes	In some areas	Yes	In some areas	In some areas	In some areas
In some areas	Yes	In some areas	Yes	In some areas	Not many	In some areas
Yes & no	Yes & no	No	Yes & no	Yes & no	No	No
No	Yes	No	No	Yes	No	No
Difficult	No problem	No problem	Difficult	Difficult	No problem	Difficult
Sometimes	Sometimes	Sometimes	Yes	Sometimes	No problem	No
Good	Sweepers' barrows small		Sweeper barrows small	Good	Good	?
Good	Covered but too high	Good	Covered	Open and too high	Good	?
None	None		Yes	Yes	?	?

2 - Country Reports for Seminar on Waste Disposal & Resources Recovery, Bangkok, Thailand September 25-30, 1978

CONCLUSION

The solid waste management situation in Asia in general needs further improvement in quality and at the present faces many problems, the solutions to which being subject to a number of constraints. The nature of the waste, climate, hygiene, living conditions, social, religious, economic and other factors in Asia are different from other countries and therefore specific solutions need to be thought of. There are already some good examples set by some municipalities, e.g. in Singapore which has achieved a high degree of solid waste management for Asia, and it is believed that there can be an exchange of relevant methods and practices of effective solid waste management through many channels including regional meetings and seminars like this one.

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REFERENCES

Chen, R.K.C., (1978) Sanitary Landfill Approach to Disposal of Municipal Refuse in a Developing Country, CDG-AIT Seminar on Solid Waste Management, September 25-30.

Espiritu, J.H. and Corazon, U.J., (1978) Solid Waste Management Report : Metropolitan Manila Experience, CDG-AIT Seminar on Solid Waste Management, September 25-30.

Flintoff, F., (1976) Management of Solid Wastes in Developing Countries, WHO Regional Publications, Southeast Asia Series No. 1, WHO, New Delhi.

Hoong, T.K., (1978) The Mechanisation of Street Cleansing in Singapore, CDG-AIT Seminar on Solid Waste Management, September 25-30.

Kim, K.H. and Kim K.E., (1978) Solid Waste disposal in Korea, CDG-AIT Seminar on Solid Waste Management, September 25-30.

Seng, N.K., (1978) Re-routing of Refuse Collection Routes in Singapore, CDG-AIT Seminar on Solid Waste Management, September 25-30.

Solid Wastes Management Report and Working Papers of a Regional Seminar, Bangkok, Thailand, October 29, November 7, 1974.

Tablante, E., (1978) The Refuse Management System in Metropolitan Manila, CDG-AIT Seminar on Solid Waste Management, September 25-30

Wah, N.S., (1978) Fleet Maintenance of Vehicles Utilised in the Collection and Conveyance of Solid Waste in Singapore, CDG-AIT Seminar on Solid Waste Management, September 25-30.

Wong, M.K., (1978) A Report on Controlled Tipping in Hong Kong, CDG-AIT Seminar on Solid Waste Management, September 25-30.

Yeo, C.B.,(1978) Solid Waste Management in Singapore, CDG-AIT Seminar on Solid Waste Management, September 25-30.

OPERATIONAL FACTORS: A REVIEW OF THE MAIN FACTORS AFFECTING SOLID WASTE MANAGEMENT OPERATIONS

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INTRODUCTION

The purpose of this particular paper is to identify and discuss the main factors which directly influence the collection, transport, processing and disposal of solid wastes at an operational level, and which must therefore be assessed and taken into account in the waste management plan. It would seem appropriate to list and examine generally the main operational factors and how they affect each stage of the waste handling system.

Fig. 1 shows, in simplified form, the main steps and alternatives involved in solid waste management. There are essentially 4 distinct functions making up the system:

- storage and collection (including separate collection of materials for recycling);
- transport;
- processing (including resource recovery);
- ultimate disposal.

These 4 functions are necessary whatever the type or origin of the waste. As we have heard, a prime aim of waste management is to ensure that solid waste is handled and disposed of as efficiently and economically as possible, with the minimum of environmental impact. However, environmental standards (and particularly operating standards) must realistically take account of present environmental, economic and social conditions, and it is a fact of life that, beyond a certain standard, increasing expenditure on waste management brings diminishing returns in terms of environmental improvement. The setting of standards for waste management will to some extent reflect the aspirations of the society, and it is the task of the planner to balance these aspirations against the limitations imposed by the circumstances prevailing in the

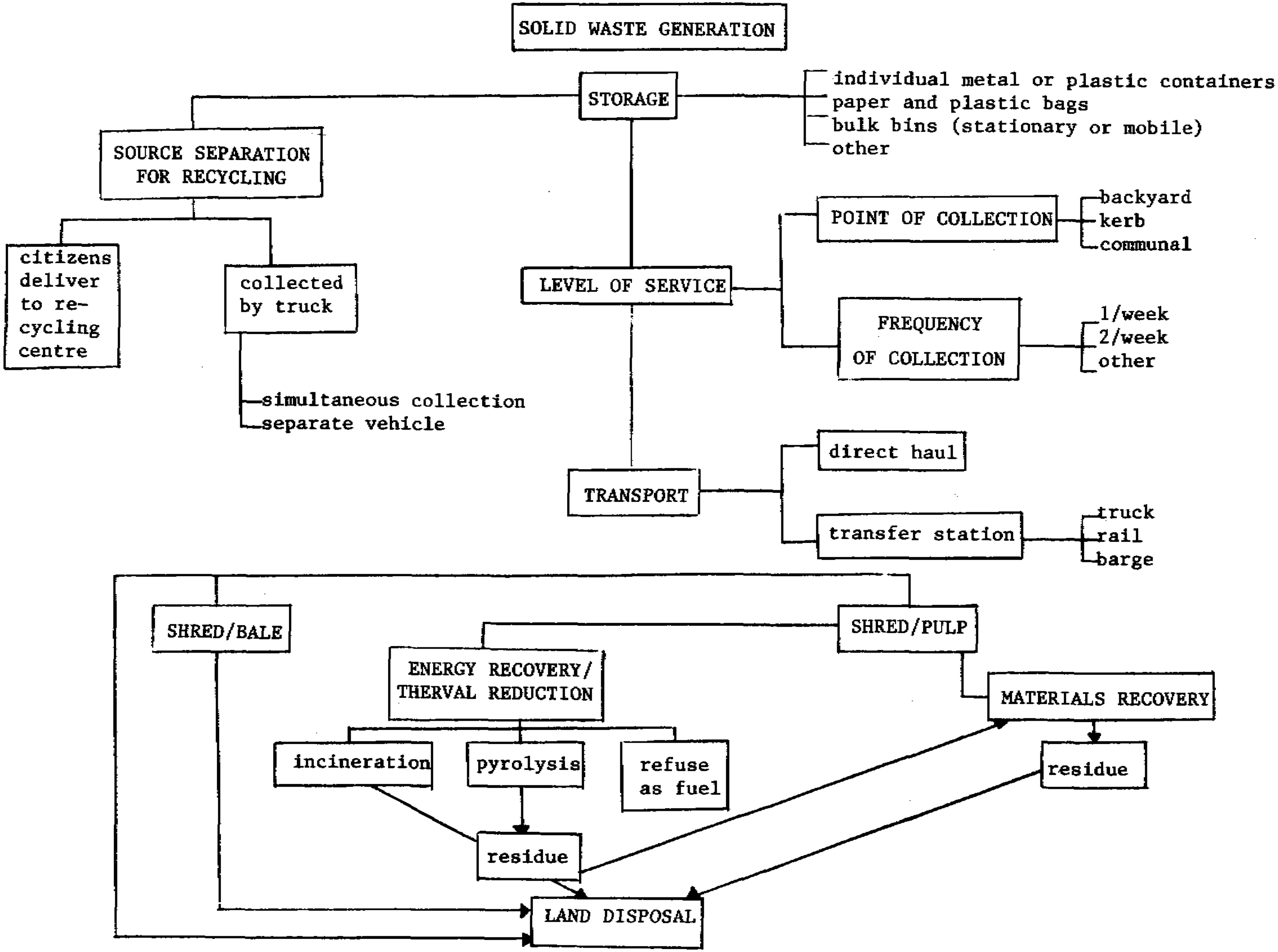

Fig. 1. Solid Waste Management Decision Alternatives

area concerned and what the society can reasonably afford. It is not intended therefore that this paper should examine the implications for waste management operations of factors introduced as a consequence of policy decisions about environmental standards, but rather to look at those factors which must be considered irrespective of any politically determined goals.

STORAGE AND COLLECTION

Whatever the prevailing circumstances, the essential starting point for a waste management operation is the provision of adequate facilities for temporarily storing the waste at the point where it arises, and this is the case for industrial solid wastes as well as household and trade refuse. In as much as problems of industrial solid waste are primarily related to their treatment and disposal, my comments on storage will be confined to those wastes, the collection and disposal of which normally fall within the domain of a public authority.

However, I would just add that it is normally in the best interests of an industrial plant operator to provide adequate temporary storage facilities for his solid waste, where these are to be disposed of outside the plant, otherwise he will very quickly find that the smooth operation of his plant is impeded.

The main operational factors to be taken into account, when deciding which form of storage arrangements are most suitable, are:

- climate;
- nature and quantity of the waste;
- physical conditions at the premises generating the waste;
- method and frequency of collection.

Climate is relevant to storage arrangements primarily with respect to potential health hazards. Generally speaking, the level of biological activity of refuse is enhanced in hot and humid climates and hence it degrades much more rapidly. In such circumstances, the waste becomes highly attractive to flies and many other pests which can be prejudicial to public health, and so it is desirable in such climates to operate a storage system which prevents access to the waste by pests and animals.

The density of the waste has a very important bearing on storage arrangements, for this determines the volumetric capacity of the container which is required to store the refuse between collections. Insufficient capacity to store the volume of waste being generated leads to spillage and stacking of excess refuse around the container, with consequent risks for health and environment, and higher collection costs. Selecting a size of container must also take account of likely trends in the density of refuse, for a well-established effect of a rising standard of living is a reducing density of household refuse and, as the proportion of paper and other packaging materials in the waste increases, the greater the volumetric capacity needed to store the waste generated.

A possible solution to the problem of insufficient storage capacity is to increase the number of containers in use at each of the premises served, but the effect of the first additional container is to add ca. 80 percent of the cost of the labour element of collection, corresponding to a net increase in the cost of collection for each house of ca. 40 percent. Clearly, it is more desirable to have a size of container such that a single container is able to take the volume of waste normally generated at the premises between collections, with some room to spare.

The other waste characteristic having some bearing on temporary storage is moisture content. Refuse containing a high proportion of wet putrescible and other organic matter is usually too moist to permit the use of paper sacks, so that rigid containers must be used. This applies also in countries where heavy rainfall is usually experienced for some part of the year.

Physical conditions for storing waste at the premises is probably the most significant factor determining the type of storage system used. The diversity of dwellings found in urban areas, particularly in developing countries, obviously precludes using any universal type of container.

The first requirement is an adequate space, suitable for standing a container. This should ideally be a well-drained, firm site, some distance from the living area. This may all sound a little obvious, but this can be a major problem in some city areas, for example, in dense, over-crowded shanty districts. Apartment blocks can also present a problem, particularly where not enough thought has gone into refuse storage facilities at the design stage. Conditions for access by collection vehicles is a critical factor, for there is no point in using individual storage containers at premises inaccessible to the collecting vehicle, e.g. in densely populated areas where made-up roads are few in number. In such circumstances, there is really no alternative but to install a communal, temporary storage system, located so as to be accessible to the collection vehicle and convenient for the residents whom it serves.

Where communal refuse storage is employed in developed countries, for instance in apartment blocks, the containers used are usually designed so that they can be mechanically emptied by purpose-built collection vehicles. In developing countries, while mechanised communal storage arrangement can also be employed, there may be other reasons why such storage systems cannot always be used in circumstances demanding communal refuse storage, e.g. lack of funds to purchase the specialised vehicles and containers, and need to employ labour-intensive collection methods, shortage of skilled labour to maintain the vehicles and specialised lifting gear, etc. In this case, one has to resort to stationary communal containers which are cleared manually by the collection crew. In terms of efficiency, this is much less satisfactory than mobile, mechanically-emptied containers, but is certainly preferable to no organised refuse storage. Much can also be done to improve the worst features of stationary communal containers by careful design, e.g. by closing them in so that other types of waste such as bulky waste and demolition waste cannot be placed in them and animals are unable to interfere with the contents, by making the cover and one side removable to facilitate emptying (possibly with the aid of small shovel-loaders, if available) and cleaning, etc.

We have already seen how refuse density affects storage capacity, and a similar influence on the sizing of containers derives from the frequency of collection as, clearly, the longer the period between collections the greater the temporary storage capacity required. However, potential health hazards constitute the most important determinant in respect of collection frequency and the minimum acceptable frequency for wastes containing putrescible matter is once a week. In certain situations, particularly in hotter climates, in densely-populated areas and where storage space is seriously restricted, a more frequent service is necessary.

Apart from storage capacity, collection frequency will also have a direct effect on costs of collection. For instance, collecting twice a week rather than once a week may be expected to increase unit collection costs by up to 50 per cent. Another significant operational factor for waste collection is the point where actual pick-up of the refuse takes place. The two basic options available are:

- collection at the kerb or roadside, where the owner of the waste places the container for collection and emptying and retrieves the emptied container;
- yard collection, which can take various forms, but essentially involves the refuse collector in carrying the waste from the premises to kerbside.

The main issue therefore is who should be responsible for transferring the waste from the premises to the kerb - the waste owner or the collector? The trade-off involved lies between convenience for the waste owner and the cost of collection. Time spent walking to the containers and carrying them is costly, and savings of up to 55 per cent on collection costs may be achieved by using kerb/roadside rather than yard collection. Besides productivity considerations, yard collection places a much greater physical burden on collection crews, which may make it much more difficult to recruit and retain manpower. Of course, there will be instances where the owner of the waste is unable to place the waste at the roadside, e.g. with elderly or handicapped people, but such cases can be accommodated fairly easily within a predominantly kerb collection service.

The main options in respect of temporary storage containers are summarised in Table 1. There is, of course, an enormous range of proprietary container systems available and, having decided which option is best suited to conditions within a particular area, the choice then depends on price, quality and, in some cases, whether the container system is domestically produced or imported.

When planning or modifying a collection system, equipment selection and crew size determination should not be made until decisions have been reached on level of service, e.g. point and frequency of collection, types of storage containers, etc. Based on these decisions, preliminary vehicle and crew size selections can be made. However, other local factors will also affect the final decision, e.g. round-trip time to the disposal site/processing plant, street widths, housing density, types of storage container used, amount of waste at each stop, payload regulations, etc. There are many types of collection vehicle available, some of which are designed for specific jobs. A basic choice is whether or not to incorporate a waste compaction system in the vehicle. Generally, it is advisable to opt for compaction vehicles to reduce haul costs and prevent the litter problems that often occur with open-top trucks. However, compaction vehicles are significantly more expensive to purchase and maintain, and there may be local factors such as lack of funds or skilled maintenance staff which may make compaction vehicles a less desirable choice. The main alternatives with regard to collection vehicle types are:

Front loaders - used to collect from bulk containers at apartment buildings, large commercial and industrial establishments, and other buildings generating large volumes of waste.

Side loaders - can be used to collect from bulk containers, but their main use is to collect from residential and small commerical premises. Suited to areas with difficult access conditions. Also suitable for servicing street sweeping and market clearing gangs.

Rear loaders - widely used for residential and small commercial collection. Best operated with at least a 3-man crew.

Satellite vehicles - used occasionally to provide for a low-density, single-family residential yard collection service. These small vehicles are serviced by a 'mother' truck into which waste collected by satellite vehicles is emptied.

Specialised collection vehicles - wide variety of purpose-built vehicles for specialised jobs, e.g. roll-on-off container trucks, lift and carry trucks. Usually used to service large waste payloads and specialised wastes.

Table 1 - Potential Advantages and Disadvantages of Types of Municipal Solid Waste Storage Containers, and Conditions that Favour the Use of Each.

Alternatives	Potential Advantages	Potential Disadvantages	Conditons which Favour Alternative
Paper or plastic sacks	Easier to handle - no lids to be removed or replaced. Less weight to lift. Reduces spillage and blowing litter when loaded in truck. One-way container - no bins left at kerb. Eliminates odours and necessity to clean dirty bins. Prevents fly entrance. Increases speed and efficiency of collection. Reduces contact of collector with waste.	Cost per sack. Sacks can fail if filled too full or if too thin. Susceptible to animal attacks. Not suitable for bulky, heavy or sharp objects. May be difficult to obtain locally.	Kerb collection.
Metal or plastic bins (75ℓ to 110ℓ)	Reasonable size for collector to lift. Economical.	Must be cleaned regularly when not used with liners.	Backyard collection.
Containers for mechanised collection	More efficient than manual collection.	Residents oppose storage of other people's waste on their property.	Alley space available for storage.
Drums (210ℓ)	Better than nothing.	Lower collection efficiency. Excessive weight can result in back injury and muscle strain. Difficult to handle. Lack of lids allows insects to breed in waste and odours to escape. Rust holes at bottom of drum allows rodents to feed on waste.	As last resort.
Stationary storage containers	Better than nothing.	Inefficient - must be emptied manually. Lack of proper cover leads to insect and rodent infestation (unless designed otherwise). Necessity for hand shovelling of wastes poses health hazard to collectors.	As last resort.

Other operational considerations relevant to vehicle selection include overhead clearances under bridges and at workshops, the availability of parts and the extent of manufacturers' local back-up service. Decisions also need to be made on such items as transmission and fuel type. Automatic transmissions are initially more expensive, but over the life of the vehicle the cost of clutch replacement will often exceed the initial difference in cost between manual and automatic transmission, and automatic transmissions are also easier to drive and safer in hilly areas. Chassis and body replacement policies should be included in long-term procurement plans. Chassis replacement will depend upon engine operating hours, which is related to vehicle distances covered, and the need for replacement should be calculated on an individual basis taking into account the costs of repair and downtime on older vehicles. In summary, decisions on vehicle types and crew sizes are highly dependent upon local operating factors, and collection systems must be frequently reviewed to make sure that current decisions on equipment and manning reflect changes in system parameters, such as waste generation, traffic congestion, road conditions, haul distances, etc.

TRANSPORT

Where a site suitable for the controlled tipping of solid waste is available within or close to the main collection zone, then, without any doubt, the cheapest method of transporting and disposing of the waste is to haul it in the collection vehicle for direct tipping. However, many urban areas in both developed and developing countries face an acute shortage of suitable landfill capacity in close proximity to the waste catchment area and are therefore confronted with having to haul the waste to landfill sites remote from the main collection zone. (It is, of course, possible to build and operate a waste treatment/recovery plant close to the collection zone in order to substantially reduce the volumes of wastes which must be tipped. This possibility is commented on further below, and is the subject of detailed consideration in other Seminar papers). In these circumstances, transporting the waste directly in the collection vehicle can result in many man-hours being spent on hauling solid waste from the collection zone to the disposal site and higher-than-need-be operating costs. This situation may be alleviated by using a transfer station. In simple terms, this is a facility where solid waste from relatively small collection vehicles is placed into relatively large vehicles before being hauled to the disposal site. The small vehicles need not necessarily be confined to public authority collection vehicles; such a station could also serve private vehicles delivering other wastes suitable for tipping, e.g. bulky waste (where reduction plant is installed at the station), commercial and industrial refuse.

Transferring waste for bulk haul represents an additional materials handling step, and will clearly involve costs for constructing and operating the plant. The associated costs must be offset by greater savings in collection transport costs for a transfer station to be justified. The resulting savings are essentially twofold:

- the non-productive time of collectors is cut since they no longer ride to and from the disposal site; it may be possible to reduce the number of collection crews needed because of increased productive collection time;
- the reduction in distance travelled by the collection trucks leads to reduced operating costs.

There is no generally applicable rule about when a transfer system should be employed, for much will depend upon local conditions, e.g. quality of roads between the collection zone and disposal site, quantities of waste being handled, local labour costs, etc. However, where any significant amount of waste has to be transported more than about 10 km to be disposed of, then a transfer arrangement should be examined carefully to see if this offers any potential saving.

There are 3 possible alternatives for transporting the waste from a transfer station to the disposal area: by truck, by rail and by barge.

Truck transport is by far and away the most common method of bulk hauling waste, and there is a wide range of equipment specifically designed for this purpose. There are basically 2 types of system for transferring the waste into large, bulk-haul vehicles.

The first is the direct-dump arrangement whereby a collection vehicle empties its load by gravity into an open-top trailer. The trailer is located under a hopper to prevent spillage, and a back-hoe is usually used to distribute the load and impart a certain degree of compaction after it is placed in the trailer. A variation on this arrangement uses a tipping bunker where a crawler tractor crushes and compacts the waste before pushing it via a hopper into the trailer.

The second basic type of system relies on hydraulic pressure to achieve horizontal compaction of the waste within the trailer. The compaction equipment may take the form of an hydraulically-powered traversing bulkhead, self contained within the trailer body, or a separate, stationary compactor which uses rams to force the waste forward into the trailer.

Either method of compaction can easily produce the maximum design payloads of the container vehicle. A transfer station may also incorporate more sophisticated volume reduction equipment such as baling or shredding. However, the main advantage of baling or shredding lies not so much in the reduction of transport costs (where in my view this brings little in the way of further savings over and above that achieved with the compaction methods described above), but rather in providing a better form of material for landfill operations. Shredding or baling can also be of help in gaining public acceptance of landfill site.

Rail haul of waste is finding increasing popularity in developed countries, e.g. in London, but this depends on there being a rail link between the collection area and the disposal site. Many worked-out mineral quarries or opencast mines already have a rail-spur installed, and where it is decided to reclaim these sites by sanitary landfill of waste, then it may be possible to utilise the rail link and spur to transport the waste. Nevertheless, substantial capital investment may be needed to provide suitable rolling stock in which case the site would need to have a fairly long disposal life expectancy to justify the cost. A few cities around the world use barges to transport waste to remote landfill sites, e.g. New York and London, but clearly there are few instances where barging offers a practical option.

PROCESSING (INCLUDING RECOVERY)

The main purpose of processing solid waste is to reduce or remove some of the objectionable or undesirable characteristics of the waste, e.g. its volume, its unsanitary nature, its toxicity, prior to final disposal. Some forms of processing are aimed essentially at waste treatment, for example:

- shredding/baling;
- incineration (without heat recovery);
- de-watering (pre-treatment of sludges);
- neutralisation, filtration, solidification, etc. (of potentially hazardous semi-solids and solids).

Others are oriented towards the <u>recovery</u> of useful products from solid waste, e.g.

- composting;
- materials sorting;
- incineration (with heat recovery);
- pyrolysis;
- waste-derived fuel recovery;
- methanation;
- hydrolysis.

Except in very favourable circumstances, none of the recovery-oriented processes are able to recover 100 percent of the waste input, so that there almost always remains a residue to be finally disposed of. In practice, waste <u>treatment</u> and <u>recovery</u> are inextricably linked.

For instance, a plant which started life as a pulverising transfer station may subsequently be altered so as to recover a waste-derived fuel and ferrous scrap. The plant then still functions as a transfer station, still treats the waste to reduce its volume (though now to a much greater extent), but also recovers 2 useful products. Some types of solid wastes do not lend themselves readily to treatment, e.g. certain kinds of demolition waste, excavation wastes, mining spoil.

Decisions about treatment and/or recovery of solid wastes involve consideration of a large number of interrelated factors, most of which are location-specific. The main questions which need to be answered before decisions on treatment/recovery can be taken are listed in Table 2, together with those factors which usually have a prime bearing on the analysis which must be undertaken to provide satisfactory answers.

Whether or not to treat a waste depends primarily on its nature, quantity and composition, and this again underlines the importance of acquiring a detailed knowledge of the types and quantities of waste arising in an area. Some waste are potentially very hazardous in terms of both the human and natural environment and treatment is usually essential to render them innocuous, e.g. hospital and medical wastes. Other types of waste, e.g. many kinds of industrial wastes, have some potential risk for health or the environment, but can, in the right circumstances, be disposed of safely with little or no pre-treatment. Here, the suitability of the disposal site is the determining factor in respect of whether or not treatment is desirable.

Landfill for potentially hazardous waste relies largely on factors such as breakdown, dilution and dispersion, and seeks to avoid wherever possible long-term problems due to concentrated and persistent waste. Such sites should also be located in relatively insensitive areas where the risk of damage to health, ground and surface waters and ecosystems is at a minimum. If no suitable landfill site is available locally to take potentially hazardous industrial waste, then treatment is the only alternative (unless, of course, it is possible to transport these wastes to a more suitable, remote landfill site).

In many countries, the government authority responsible for waste management is able to place the onus for safely disposing of these wastes on the originator. However, if no private treatment facility is available to take these wastes, then it may make sense for the authority to build and operate an industrial waste treatment plant, or charge industry for treating its hazardous wastes. This will often be a cheaper option for industrial waste producers than building and operating their own smaller treatment facilities, and at the same time reduces the temptation to dump illegally.

Most solid waste, e.g. household refuse, demolition waste, mining waste, would not normally pose a serious threat to health or the environment if disposed of on land in a controlled manner. With these wastes, treatment is undertaken to reduce their bulk, make them easier to handle,

Table 2 - Factors Affecting Decisions on Whether not to Treat or Recover Wastes.

Information needed to take decisions	Factors which must be examined
1. Is there a suitable landfill site for the type of waste requiring disposal, with sufficient capacity for the period covered by the waste management plan?	- capacity of site. - types, quantities and density of wastes requiring disposal. - hydrogeological suitability of site. - adequacy of access to the site. - potential impacts on local inhabitants, wildlife and amenities of the area. - traffic congestion. - planned subsequent use of the reclaimed site. - enhanced value of the land when reclaimed. - estimated capital and operating costs of site.
2. Is a transfer station desirable?	- distance of disposal site from collection zone. - transport options for bulk haul. - types and quantities of waste to be transported. - nature of route from collection zone to disposal site. - traffic conditions on route.
3. Would treatment of the waste be necessary or desirable?	- types, quantities and composition of the waste. - hydrogeological suitability of final disposal, etc. - capacity of final disposal site. - implications of treating the waste for reducing potential environmental impacts at final disposal site. - availability of sites within or near waste catchment area for treatment plant itself and potential effects of treatment facility on the environment. - estimated capital and operating costs of alternative treatment facilities - distance between possible sites for a treatment plant and final disposal site (and associated route and traffic conditions).

Table 2 - (Continued)

Information needed to take decision	Factors which must be examined
4. Is it feasible to recover materials, energy or other by-products from the waste?	- types, quantities and composition of the waste. - market potential for any recovered products (demand, likely revenue from sale of recovered products, location of potential outlets for recovered products). - extent to which resource recovery might reduce tipping capacity required (or extend the useful life of existing disposal site). - extent to which recovery might reduce potential environmental impacts at final disposal site. - costs of recovering products from waste, and effect of recovery on overall disposal costs. - potential consequence of recovery for employment, resource conservation, balance of payments, and other national considerations.

and to give a better material for landfilling. Where, for example, an existing landfill site within or near to the waste catchment area is being used to dispose of untreated household refuse and similar wastes, treating the waste to substantially reduce its volume (e.g. by incineration) may enable the authority to postpone opening a further site by extending the life of the present site, and also to improve conditions at the existing site. The authority may even be faced with a shortage of local tipping capacity such that once the present site is exhausted, the waste would have to be transported a very long distance for final disposal. In such cases, treatment may be justified on economic as well as environment grounds. It can be seen therefore that decisions about treatment tend to be very waste and location specific.

The attractiveness of recovery as a method of handling wastes depends primarily on how the costs and benefits of the available recovery methods compare with the costs of the conventional methods of waste collection, treatment and disposal that would otherwise be employed.

From the point of view of the responsible authority, recovery should be of interest if: the cost of collecting the material or product plus any cost of sorting or separation of the materials, or processing into by-products less any saving in overall waste collection and disposal costs is less than the revenue obtained from the sale of recovered materials, energy or other by-products.

In operating terms, the viability of recovery is highly dependent on there being a stable market for the recovered products in the vicinity of the waste handling plant (or collection area in the case of separate collection of materials for recovery), and on the prices obtainable for the products. Another important factor is the operating reliability of the recovery method, for constant breakdowns and persistent shortcomings in performance can make recovery more expensive than handling and disposing of the waste in a conventional manner.

It is not intended to go into any details of different methods and technologies for recovering valuable products from solid wastes here. However, it is perhaps worth stressing that the nature and composition of the waste is of crucial importance in assessing the recovery potential of a waste. Highly mixed and contaminated wastes, containing low value substances in low concentrations often offer very little potential for recovery, unless the waste possesses certain characteristics which are favourable to thermal or biological conversion into useful products, e.g. methane from sewage sludge. Industrial waste is normally recovered extensively in-plant for economic reasons, so that much industrial solid waste is not suitable for processing to recover products. Undoubtedly, the greatest potential for resource recovery lies in post-consumer solid wastes, particularly municipal solid waste, and it is with these types of waste that greatest progress in recovering useful products is likely to take place in future.

FINAL DISPOSAL

The most common (and usually the cheapest) form of final disposal for solid waste is landfill, and I have already commented on the nature of the key factors affecting the operation of final disposal sites. Other means of final disposal are dumping at sea and subterranean deposition. Again, the subject of sanitary landfilling of solid waste will be dealt with in another paper, but it is perhaps worthwhile to list the key operational factors which need to be examined before selecting a landfill site.

These fall broadly into the following categories:

- the nature, quantity and composition of the wastes, in relation to the capacity available at a potential site;
- potential environmental impacts which might result from taking a site into use for disposal of these wastes;
- the planned use of the restored site; the amount of landscaping, top-soiling and planting necessary.

The nature, quantity and composition of the waste in relation to disposal capacity has already been discussed under processing. In respect of potential environmental impacts, a properly located, designed and operated landfill site should not lead to any serious pollution problems or health hazards. Probably the most important environmental factor to be examined at a potential landfill site is the pollution risk to ground and surface water. The physical, chemical and biological barriers to migration of any leachates must be considered together with precipitation, direction of ground flow, rate of deposit and degree of dilution.

For most new sites, it is necessary to carry out a hydrogeological survey of area which can, in some cases, involve the construction of bore-holes. A factor which should not be ignored during any exercise aimed at identifying and assessing potential landfill sites, is possible public resistance and objection to the site being used for waste disposal. Clearly, it is desirable to try and select a site well away from any settlements, but inevitably a landfill site will intrude to some extent upon the amenity of the area in which it is located. Publicity of the benefits of reclaiming derelict land often goes a long way towards gaining public acceptance, but certain conditions may be necessary as a result of a public inquiry, e.g. that the waste is shredded or baled, or that certain classes of waste cannot be tipped. Finally, the proposed use of the reclaimed land should be determined prior to commencement of operation, in order to achieve the necessary finished levels and degree of stability. This can also serve as a useful aid in winning over public opinion in support of the scheme.

COLLECTION AND TRANSPORTATION OF SOLID WASTES IN ASIA

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INTRODUCTION

The complexities of solid waste management are not readily appreciated. There are numerous sources and types of solid wastes ranging from the home to the farm and from refuse to industrial wastes. Handling involves storage, collection, transfer, and transport. Processing includes incineration, densification, composting, separation, treatment, and energy conversion. Disposal methods show the environmental inter-relation of air, land, and water, and the place of salvage and recycling. All these steps introduce constraints — social, political, economic, technological, ecological, information, and communications — that must be considered in the analysis of the problem and in coming up with acceptable solutions. The discussion that follows will principally deal with the collection and transportation of solid wastes in Asian developing countries.

In any solid waste system, the greatest costs are incurred at the collection stage and so the greatest care should be taken to arrive at management decisions which optimise the resources available for this part of the service. In this connection, there are many modern planning and management techniques which allow collection decisions to be made rationally with full evaluation alternatives. Many facets of the solid waste collection subsystem are amenable to analysis using the techniques of operation research.

SOLID WASTE COLLECTION SYSTEMS (PESCOD, 1975)

Vehicular collection is by far the most common throughout the world. The components of vehicular collection are principally the trucks, the crews and, sometimes, transfer stations. Of vital importance to the efficiency of collection are the types and sizes of refuse storage containers at source, the crew's size and method of pick-up, the type of trucks and their scheduling and the location and organisation of transfer stations or disposal sites.

Evident are the advantages of standardisation of refuse storage containers and these will include the expediting of the manual pick up by a collection crew. It will also affect the decision by crews to adopt transfer containers, which are often used to transfer solid waste from several service points to a truck when a wide range of household container sizes are met with in an urban area. Large baskets are commonly used as transfer containers, being cheap and lightweight. Ideally in the hotter countries of Asia, solid waste should be collected daily from each household and commercial or industrial locations but market areas might require an even more frequent pick-up schedule. Street sweeping is an important function in metropolitan areas and must be included in the collection process. If individual street sweepers are equipped with simple but sturdy handcarts capable of transporting removable containers of 100 to 200 litres capacity, they can operate within a 1-kilometre radius of a transfer site where a trailer can be parked for haulage on an exchange basis.

The size of crew associated with a single pick-up vehicle will depend on local requirements but even this can be evaluated and optimised using techniques to be discussed. Organisation of the tasks of a crew will depend on the type of storage container to be handled, the spatial distribution of pick-up points, use of transfer containers and the type of collection vehicle. A relay system may be adopted to fully utilise a crew during the vehicle travel time to a disposal site, in which case more than 1 vehicle is served by crew. This will be economic where the haulage distance is great.

Trucks commonly used for solid waste collection in many Asian countries are not particularly adapted to the function and the economics of the collection service is adversely affected as a result. Collection of refuse should be with closed vehicles having a low loading height and they should be equipped with tipping gear. Although labour is relatively cheap in developing countries, the amortised additional cost of custom built vehicles would be more than offset by the saving in additional labour costs resulting from time-saving on loading and unloading. Fleet standardisation is also strongly recommended to minimise the stock of apare parts and simplify maintenance. In order to ensure prompt and efficient servicing of collection vehicles, the public agency carrying out the solid waste service should also be responsible for vehicle maintenance. It is common in developing countries to see very old vehicles being used for refuse collection but it is also common for authorities to have poor records of vehicles in service. In most countries it will be the case that the cost of maintaining vehicles 8 years old or more (or with accumulated mileage greater than 100,000) will be greater than the cost of vehicle replacement. As it is desirable to achieve maximum deployment of vehicles, it will be economical to schedule vehicle replacement on a regular basis utilising a sinking fund financing system.

As for the type of vehicle, a low-loading, automatic tipping non-compression truck will normally be most popular for urban areas. However, the concept of separate trailer and motive units is worthy of consideration. Since the power unit is the most costly part of the collection vehicle, if a single power unit can service a number of parked trailers the investment in vehicles will be reduced. Trailers could be locally made in most countries but should still be the tipping type. Compression-type vehicles could be used in areas with low density waste but these would add to costs and maintenance problems. The size of the collection vehicle is also important, with a larger vehicle requiring fewer trips to the transfer or disposal point in a day. However, a larger vehicle will cost more and may be unsuitable from the point of view of access to service points in densely-populated areas. Here again, alternative sizes of truck capacity can be evaluated using simulation techniques. Very large vehicles (or sometimes even rail transport) are often used between transfer stations and disposal points.

The optimum scheduling and routing of collection vehicles is essential if a solid waste system is to operate efficiently and economically. Many techniques are available to make best use of vehicles, equipment and facilities and some of these will now be reviewed.

ANALYSIS AND MODELLING OF COLLECTION SYSTEMS

Planning of solid waste systems can rarely be done from scratch, except for new towns, and most planners will be faced with the problems of optimising and/or expanding existing systems. Being the most expensive part of the total solid waste system, collection deserves the greatest attention but trial and error methods are unlikely to arrive at optimum solutions in reasonable time. The use of systems analysis and operations research techniques, given the availability of computer facilities, will enable a wide range of variables and alternatives to be studied with a minimum of data collection. Some techniques which have been applied to solid waste collection are Monte-Carlo Simulation, Linear Programming and Queuing Theory.

Monte-Carlo Simulation

When an event is stochastic in nature the average value has very little significance except as an estimator of the long term trend. The event itself is better described by the probability density function (pdf) which gives the relationship of the occurrence of one event with respect to another. Moreover, when the system is made up of a sequence of events (such as, moving from one collection stop to another, transfer of waste from a collection truck, loading waste into a truck and returning the empty containers to the original site), the probability distribution of the total time is difficult to define. Unless the pdf is a normal distribution, the sum of the averages does not give the average of the total distribution. For example, the sum of events with exponential distributions is defined by a gamma distribution. The shape and properties of the gamma distribution is different from the exponential distribution.

Considering the collection system, it can be deduced that most of the variables are stochastic in nature. The stochastic or deterministic nature of a variable is dependent on whether the next event can be predicted without or with certainty. If the next event can only be expressed in terms of chance of occurrence, then it is stochastic. For example, in a residential area some houses may have one waste container, some 2, some 3, and some 4 or more. Before the next collection stop is reached, the exact number of containers cannot be known but, from previous studies, it may be possible to predict that 50 per cent of the time there will be one container, 25 per cent of the time 2 containers, etc., so that the variable is stochastic.

A case study of the application of the Monte-Carlo technique has been discussed by OUANO and PESCOD (1974) considering the collection process as a system. The first approach is to break down the system into its components or steps as shown in Fig. 1, which gives the sequence of variables and indicates where decisions are made. The system's graphical model can easily be constructed by observing the process itself.

After the sequence of operations has been developed and identified, field studies can be designed to measure and define the values of the variables. The practical experiment can be conducted by following a collection crew for a number of days in different types of collection areas and recording the values of the variables. Statistical analysis of the collected data is then carried out to determine the pdf.

A more sophisticated means of measuring crew performance is to record the whole sequence on a video tape provided with a time recorder. In cases where the experiment is conducted in a standard motion study laboratory, the video tape could record a wall clock in the background. The advantage of this method is the ability to replay the sequence and study the process more closely. As the video tape can be replayed and run at speeds slower than the actual speed, details of the process which could have escaped observation in the field may be noticed and examined closely.

Sometimes the motion study is conducted not only to measure crew efficiency, but also to determine the standard time to accomplish a piece of work. In this case, a properly selected working crew will be observed in the laboratory performing the same sequence. Details of this procedure are given by STONE (1969) and BARNES (1968).

A simulation model can be constructed by generating random variates for the different distributions. The first important step after the model has been developed is to compare the output of the model with actual field data. If the results are close to each other, say error is less than 5 per cent, then the model is said to be validated.

After validation, the variables which could be controlled by the organisation, such as truck size, crew size, container type, collection type, are varied. This is known as the sensitivity test and the purpose is to identify those variables which have the greatest effect on the

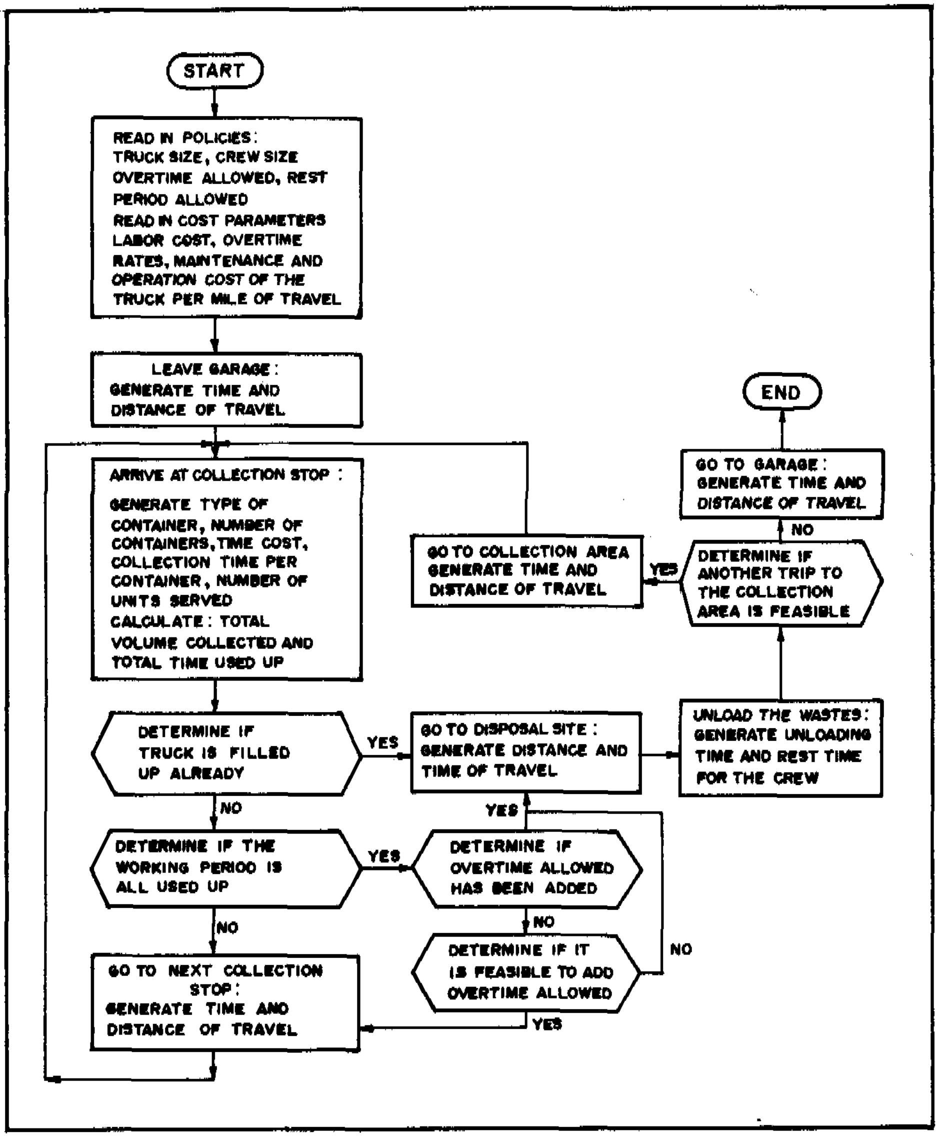


Fig. 1. Collection System Computer Simulation Model Flow Chart

system. The management will then have an idea of which variables should be watched closely and which could be taken for granted. In this way a supervisory routine of inspection and reporting could be better developed.

The next important function of the model is for system improvement. Consider the situation where there are 4 choices of truck size, 6 choices of crew size, 3 choices of container types, and 3 collection types. The total number of possible combinations is then equal to (4 x 6 x 3 x 3) = 216. Using previous field experiment methods, it would take 3 years or even more to study the performance of the 216 combinations. However, with the simulation model, where the effect of these variables has been segregated, only (4 + 6 + 3 + 3) = 16 field experiments need be conducted. The 216 experiments can be carried out using the computer to study the combined effects of the variables. It is worthwhile noting that the behaviour of the system under a wide variation of options can be obtained in a much shorter time using the simulation model, in this case in almost 1/10th of the time using 216 field experiments.

In addition to deciding the physical components of the system, such as manpower and trucks, decision policies could also be incorporated in the model. The decision policies are mostly those which deal with overtime, deciding when to send a truck back to the collection area after a trip has been completed and to what collection area, and the task system for the collection crew. The analysis of these policies has been studied by STONE (1969), QUON et al (1969) and OUANO and FRANKEL (1974). In the first 2 studies, the decision policies for the truck to return to the collection area after a trip had been completed were derived empirically, whereas in the latter paper an economic evaluation of the factors that affect the cost of collection per trip was made and decision criteria were geared towards determining the minimum operating cost. In all cases, the decisions were tested using a simulation model. It should be noted at this stage that a wider variation could exist for the collection policies than in the choice of the physical system components. Therefore, a larger saving of time and money could be realised in this process. Moreover, the testing and development of policies involves very little actual field experimentation as it is dependent for input on the physical components which make a computer model highly attractive compared with physical experimentation.

Linear Programming

The linear programming technique is most often used for allocating resources to different uses and optimising the overall objective of the organisation. This has found wide uses in petroleum refinery operation, resource allocation in an economy etc. Due to its wide uses, computer package programmes are available in which the users merely formulate the linear programming equations, and transfer the coefficients and constraints into media which could be transmitted to a computer. This section will deal more with the formulation of the linear programming equations as used in the solid wastes management system. With regard to mathematical manipulation in solving the linear programming equations, standard operations research textbooks such as HADLEY (1963) and HIELLIER and LIEBERMANN (1967) could be consulted.

The main application of linear programming in solid waste management is in the allocation of trucks and men to different collection areas such that the cost of collection and disposal is minimised for the whole city. The first step in the process is to divide the city into smaller districts with very similar land use and population densities, which will hereafter be called "collection areas". The centroids of the different collection areas are determined by methods commonly used in applied mechanics. For the population and the wastes generation rate data, the volume of wastes generated per day can be determined for each collection area, noted as V_i (where i is the subscript for the different collection area).

From the simulation model, the cost of collecting wastes using a given truck size, crew size, land use and distance between the collection area centroids and disposal site could be determined, denoted by $C_{i,j,k}$ (where i denotes the collection area, j the truck size and type, k the disposal site at which the truck will unload the wastes collected). The choice of crew size has been determined from the simulation model itself, and the land use from the existing characteristics of the collection area. Similarly, the total volume of wastes collected per day per truck, $V_{i,j,k}$ could be determined from the simulation model for a given truck size and type, collection crew size, type of land use and distance between the collection area and disposal site.

If the disposal site k has a definite size, then the cost of disposal at the site k can be determined and denoted by D_k. Then the total cost of collection and disposal for the whole city can be expressed as Z, which is also equal to:

$$Z = \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{o} (C_{ijk} + D_k) \; T_{ijk}$$

where, $T_{i,j,k}$ are the trucks coming from collection area i unloading to disposal site k of type j.

The constraint to this equation is the number of trucks available of each type, j, which gives:

$$\sum_{i=1}^{n} \sum_{k=1}^{o} T_{i,1,k} \leq A_1$$

$$\sum_{i=1}^{n} \sum_{k=1}^{o} T_{i,m,k} \leq A_m$$

where, A_j is the truck of type j available

The other set of constraints is the wastes that must be collected per collection area:

$$\sum_{j=1}^{m} \sum_{k=1}^{o} V_{1,j,k} T_{1,j,k} \geq V'_1$$

$$\vdots$$

$$\sum_{j=1}^{m} \sum_{k=1}^{o} V_{n,j,k} T_{n,j,k} \geq V'_n$$

The third set of constraints is the capacity of the disposal facilities at the kth site, which gives the following equations:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} V_{i,j,1} T_{i,j,1} \leq S_1$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} V_{i,j,o} T_{i,j,o} \leq S_o$$

All $T_{i,j,k} > 0$.

where, S is the size of the kth disposal facility.

For the solution of the number of linear equations with inequality constraints, the simplex method could be used. For discussion of this method, refer to a standard text or reference in operations research.

The result will give the number of trucks that serve the disposal site i and unload at the disposal site k. CLARK and HELMS (1970) first used these techniques in allocating the different vehicles to decentralised waste collection facilities. The solution of large linear programming tableau is very difficult to achieve manually or even with very small computer systems. Where large numbers of semi-skilled workers are available, the construction of iso-cost curves based on previous data of different trucks serving the collection area i and disposal site k is possible. An iso-cost curve is very similar to an elevation curve on a contour map. The curve represents the cost as a function of the distances from one collection area and disposal site, around the city. It is logical to say that the cost will be lowest for the areas near the disposal site and will rise for remote areas. However, the iso-cost curve will not be circular because land use will vary across the city. The boundary for the different collection areas which should dispose of waste to disposal site k can be determined by studying the different iso-cost curves. This method is simple but lacks the ability to assign different truck types simultaneously throughout the city.

No existing use of the method has been published but it has been widely used in industrial logistics for very similar problems. Nowadays it is usually neglected due to the large amount of data and semi-skilled manpower requirements but may be appropriate in developing countries.

Queuing Theory

Queuing theory has found application in the design of unloading facilities at a disposal site. Most often the regular working day starts simultaneously for all crews but, since they are sent to collection areas at varying distances from the disposal site, they arrive at the disposal site at different times of day. Sometimes a large number of trucks will arrive at the disposal site simultaneously, when some will have to wait in line while the other trucks are unloading. In this case, waiting trucks will mean time lost in the utilisation of crew and truck. However, increasing the number of unloading facilities at the disposal site will also mean an increase in the cost of construction for the disposal site. When the distribution of the time it takes to unload a truck is a gamma or exponential distribution and the arrival rate of the trucks is a Poisson distribution, standard mathematical formulae have been developed to predict the number of trucks waiting, and the average waiting time for the trucks. The cost of the waiting trucks can be estimated from the idle labour and equipment. When the number of unloading stations increases, the cost of idle machines and manpower decreases while the cost of the unloading station increases as shown in Fig. 2.

When the distributions of arrival time and service time are not exponential or gamma, the Monte-Carlo technique of simulation has to be used as QUON, CHARNES and WERSAN (1965) have done. In their experiment, they found the ideal number of 3 to 4 trucks per unloading dock. In developing countries, where the manpower cost is much lower than in the United States, the number of trucks served per unloading dock could be much higher as the cost of waiting is smaller compared with the capital cost of constructing additional unloading docks.

REFUSE STORAGE METHODS IN ASIA

The rapid increase in solid waste generation in Asia is posing a serious problem and a solution to it is a must in the collection process. Storing the refuse is the only way in which collection process can be facilitated and at the same time minimises the cost of collection. Without refuse storage, substantial proportions of the waste produced are not collected. These uncollected wastes will accumulate in courtyards and waste grounds, will be thrown into rivers or ditches and in most cases will be blown by the wind.

There are 2 types of refuse storage methods which are commonly used

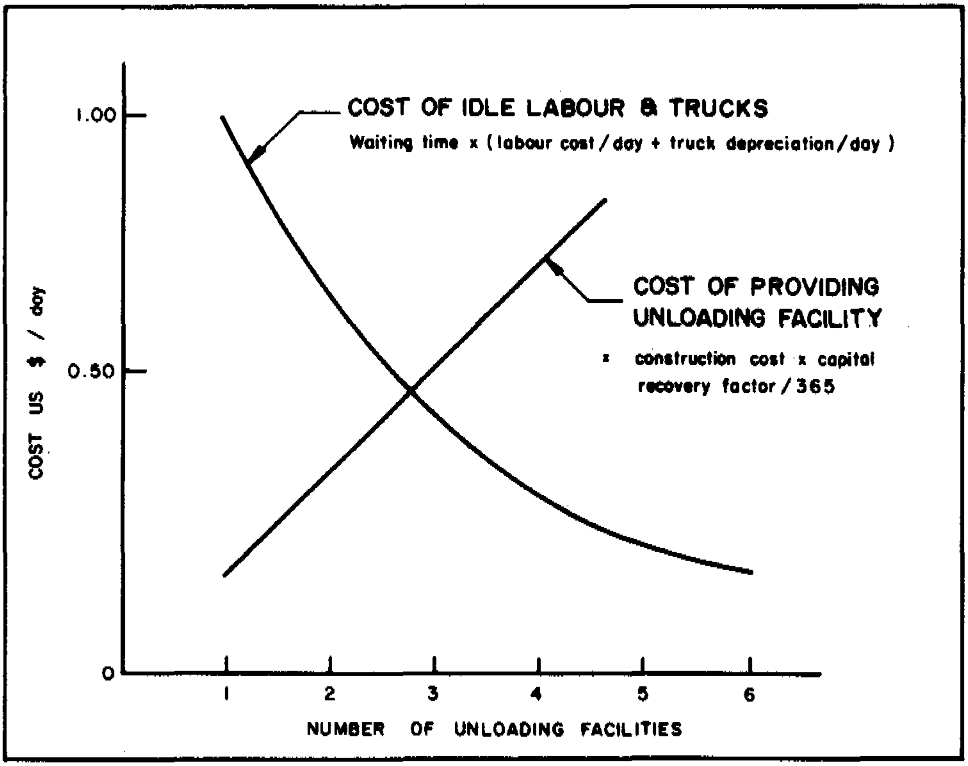


Fig. 2. Economics of Determining the Ideal Number of Unloading Facilities at Transfer Stations or Disposal Site

in Asia, namely: the communal storage method and the household storage method.

Communal Storage

In the communal storage method, wastes are stored in communal containers provided, in most cases, by government officials. The residents themselves deliver their wastes to the containers. These containers should not be located very far from the houses, otherwise residents will be encouraged to dispose the wastes on the pavement or the nearest available area. The spacing of the containers is determined by their capacity and the population density of the area. The closest spacing observed is in Rangoon and the widest is found to be in Delhi. The distance between the containers in Delhi explains the existence of private collectors and the employment of large number of street scavengers.

Communal sites may take in many forms:

1. Depots which consist of a large garage or the ground floor of a multi-purpose building. The capacity of depots may be as great as $25m^3$. Commonly, depots are used for storing wastes at large markets and in some Asian countries, they are adopted for the storage of domestic and trade wastes. In Delhi 150 buildings are used as depots and the average capacity of each is $12m^3$, which is equivalent to a population of 10,000 or more at the present generation rate. This kind of storage is only really effective and practical in densely-populated areas where it can be spaced properly.

The advantages of depots are that animals and scavengers are prevented from gaining access to the wastes; the wastes are protected from the rain thus production of foul smells and the breeding of flies are inhibited.

In spite of these advantages, depots are not highly recommendable because there is a problem in the acquisition of the sites for storage depots. The area occupied by depots is equivalent to a large shop and the location must be near the road wide enough for vehicle access and this site is often very costly to acquire.

2. Enclosure is found to be widely used. Its essential feature is a wall of timber, corrugated iron, brick or concrete which screens and contains the wastes. The screen has one or more openings through by collectors. The average capacity is 1-10 m^3 having an average throughput of 2 m^3/day. This method would serve 2,000 people at the minimum generation rate.

In many cases in Asia, enclosure is found to be a failure because rain, animals, flies and scavengers are free to come in contact with the wastes. Also wastes are thrown just inside the entrance where a heap builds up, thus blocking access to the main area while wastes overflow from the entrance. Sometimes enclosures are used for urination and defecation purposes, increasing the health risk to the workers.

3. Fixed Storage Bins are also commonly used in Asia. Usually, they are built from concrete blocks. Such a bin has no entrance like the screened enclosures. The wall is considerably high about 1.2-1.5 metres for the wastes to be dropped inside and as a protection from scavengers and animals gaining access to the wastes. In one side of the wall, an opening, covered by a flap is provided through which the wastes are removed. The average capacity is about 2 m^3. In some Asian nations this method fails because a great health hazard to the workers collecting the refuse. Further, the flaps covering the bottom opening tend to break off and disappear so that the contents overflow. Because of the height of the wall, residents tend to dump their wastes outside the bins and not inside it.

4. Concrete Pipe Sections are used in some Asian cities with a low population density. The most common size is about 1 metre in diameter, the length being of similar or shorter dimensions, providing a volume of about 300 litres. Major objections are: wastes are exposed to view; they are accessible to flies, rats, domestic animals and scavengers; are difficult to be racked away; and provide the worker with intimate contact with the wastes.

5. 200 litre Drums are most widely used throughout the world. Depending upon the nature of the contents, the total weight would be in the range 35-115 kg. Handling should always be by 2 men, because of the awkward size of the drum and its lack of lifting handles. With good management, 200-litre drums would greatly increase efficiency and may be advantageous over present methods. A few cities in Asia have demonstrated that is possible to use 200-litre drums with reasonable success under the management of the local authority: the drums have been painted inside with bitumen paint; locations have been carefully selected, paved and provided with partial fencing; damaged bins are quickly replaced; and collection is conducted daily.

Household Storage

Household storage is used to supplement the function of communal storage bins. Each family is requested to use containers to store their daily generated wastes and these wastes are dumped at the nearest communal storage facility or brought directly to the disposal sites. The volume of the container to be used is a function of generation rate, family size and frequency of collection.

As in communal storage, a capacity margin should be provided as an allowance during weekends, holidays and other special occasions because generation rate is higher than normal. This method of refuse storage is very practical and convenient for a door-to-door and kerbside collection system.

The common types of household containers are: plactic buckets with lids which are suitable for a daily collection; plastic bins with lids which are ideal for twice a week collection; galvanised steel, or plastic bins with lids which have a capacity of 50 to 70 litres used when collection is twice a week from a high-income group, or for daily collection from shops; and, expendable plastic bags. Expendable plastic bags are not successful or practical in Asia, proving to be uneconomical. The regular acquisition of bags will increase the annual expenditure. In Delhi, for example where the average annual expenditure per family on refuse collection is Rs. 0.50 (6 cents US) or less, the supply of 150 sacks even at a very low price, say, Rs. 0.20/sack would cost 30 rupees per family per year. This means that a 40 per cent increase to their normal expenditure.

The objections to domestic storage are: a constant loss of containers by theft or when residents move house and the diversified function of plastic bins being used as storage for food and water.

Most Asian countries are now facing a dilemma over refuse storage and collection because there is no legislation covering the provision of storage containers for refuse at the point of generation. People are using different types and sizes of container which add considerably to the collection time. In addition, infrequent and irregular collection offers another problem because it will result to overloading of storage containers leading to unsanitary conditions.

It is advantageous then to standardise the containers taking into account the generation rate and the limit of handling by single collector. Cover should be provided to protect the refuse from flies, animals and scavengers. Ideally daily collection should be organised and individual storage containers should be provided. However, the provision of containers may have to be voluntary. This can be encouraged by propaganda, mass media, etc. Large containers should be used for commercial and industrial application and should also be standardised for efficiency in collection.

Several studies have already been made concerning the insect and fly breeding problem. It has been found that the garbage container and uncovered adjacent storage areas are responsible for the large accumulations of larvae and pupal life of the fly. Use of proper containers with lids and the proper cleaning of the container storage area are the immediate requirements.

COLLECTION SYSTEMS IN ASIA

Solid waste collection is the responsibility of the local government to protect the locality from pollution and degrading and, most importantly, to protect public health. Services provided by the local government are paid for through taxation or a service charge.

The collection system involves collection, storage, transfer and the transport of refuse. There are 2 collection systems operating in Asia municipal and private. Under the municipal collection system, the local government deals with a contractor. It operates on established routes serving the entire residential areas or on a scheduled basis; whereas, in the private collection system, private collectors contract directly with the household owners for an agreed fee.

The municipal system is the most economical because it can operate without a profit while the private contractor cannot, and it has a lower collection cost. If properly planned and supervised, it will provide a satisfactory service to the public.

There are 4 basic types of collection employed in Asia: house to house, communal, kerbside and block collection.

Collection from Communal Site

The organisation of refuse collection is greatly simplified by the use of large communal storage sites. Communal containers are provided where household owners deposit their wastes. The collectors just collect the waste from the site.

The effectiveness of this system depends mainly on the size of the container and the distance of the container from the house. When sites are widely spaced, a great deal of domestic wastes are deposited in the streets by householders who are too lazy to carry it to the enclosures. In this case, collection costs will increase because of the employment of street sweepers. In Delhi, for example, where there are around 1,250 sites having capacities from 0.5 to 10 tonnes and which are widely spaced, 10,000 sweepers are employed to keep the city at a tolerable standard of cleanliness. House-to-house collection has been found cheaper than to sweep refuse from the streets.

Recently, communal storage is less employed in most Asian cities because of the problems associated with it. Large and widely spaced containers are a failure due to the unwillingness of the residents to co-operate.

Additional objections to this system are that wastes are usually removed by rake or shovel and basket which is a very slow process and vehicle waiting time during the loading process is excessive thus increasing the cost of collection. The collection vehicles also tend to interfere with the traffic.

This collection system is found in Delhi, Madras, Bangalore, Manila, and Rangoon.

Block Collection

This collection system is done every 2 or every 3 days. A collection vehicle serves definite routes and stops. Usually, it stops at every street intersection where a bell is rung to inform the residents of all the streets leading to that intersection. Residents bring their waste containers to the vehicle and hand them to the crew to be emptied. Frequent collection is done so that the weight of the wastes to be carried to the vehicle may not exceed the capacity of some of the residents.

It is more advantageous than kerbside collection in a way that bins are not left out on the street for a long period thus loss is avoided. At 2-day intervals, block collection appears to be the most suitable system in Asia because it offers a low collection cost since the crew does not need to leave the vehicle and it avoids all the possible problems that arise with the communal and kerbside collection systems. As cited by FLINTOFF (1976) the daily performance achieved by this system is about 3.5 tonnes/man/day and 7.0 tonnes/vehicle/day. A 2-man crew is sufficient for this kind of collection system which is widely used in Mexico City.

Kerbside Collection

Under the kerbside collection system, residents are urged to place their bins on the pavement in advance of the collection and remove them after they have been emptied. Standard bins are encouraged for the ease of collection and to improve collection efficiency. If improvised bins are used, collection efficiency is low and the cost is high.

Residents are advised to place the bins on the verge outside the house only during the period when kerbside collection is expected. Otherwise the bins will be lost by theft. Regular collection intervals and a precise timetable is required.

Although kerbside collection is the cheapest method of house-to-house collection, it is never satisfactory in Asia. It offers several problems: bins are sorted through by scavengers and turned over by animals, thus scattering the wastes around, bins are stolen because the householder fails to retrieve the bins quickly. In addition, number of traffic accidents have been recorded caused by bins rolling onto the road. However, for some types of buildings, kerbside collection is unavoidable.

House-to-House Collection

This system is employed when communal storage fails. Usually the containers are just improvised oil drums, kerosene tanks, such as can be found in Colombo, parts of Jakarta, Bangkok and Manila. Carton boxes also are used as they can be disposed together with the wastes.

Under this system, the householder does not work. The collector enters the garden or courtyard, carries the bin to the vehicle, empties it and returns it to its usual place. This system is costly in terms of labour because of the high proportion of working time spent walking in and out of premises and from one dwelling to the next. But in Asia, this system seems to be satisfactory because labour costs are low.

The problem with door-to-door collection in developing Asian countries is that there are fewer vehicles than in Europe or the USA. It can be said that door-to-door collection by the conventional system of a heavy motor vehicle and crew is very unlikely to be viable unless the interval between collections could be extended to a week.

The main conclusions that can be drawn from what has been discussed are as follows:

- Communal storage systems based on manually portable containers probably offer the lowest collection cost.

- Block collection at 2-day intervals appears to offer a low collection cost and avoids all the problems that arise with communal storage or kerbside collection.

- Door-to-door collection by a heavy motor vehicle and crew would be by far the most expensive system for a developing country if a daily service is required. It may be financially acceptable in selected areas if a twice weekly service was adopted.

FREQUENCY OF COLLECTION

The frequency of collection is an important factor to be considered in solid waste management as it determines the overall cost. Generally, it is recommended that collection should be made once a week or on a 5 day week schedule - Monday through Friday, utilising the 8-hour work day. This appears to be acceptable to householders.

To determine the frequency of collection, the following factors should be considered:

1. Character of the waste. In the USA where wastes contain more metals, plastics and inorganic matter, a once weekly collection is sufficient. But in Asia, where wastes are high in vegetable-putrescible matter, more frequent collection is desirable. Daily collection is highly recommended because putrescible matter is a very good breeding medium for flies and other insects. Also, if kept for more than a few days, wastes decompose with undesirable aesthetic effects.

2. Climate. This is important with respect to the decomposition of wastes. Decomposition proceeds more rapidly in a tropical climate than in a temperate one. When communal storage is used, climate is the factor that really determines the frequency of collection, which should preferably be daily, or at least 3 times weekly.

3. Size of the container. Difficulty is encountered is areas where size and types of containers are not standardised. Cost of collection is considerably high because the main determinant of work content of a collection route is the number of containers to be emptied and the

distance between them. As a rule of thumb, a 100-litre bin is sufficient to meet the requirements of most houses where the collection is made once a week.

The size of the family will determine the size of the container. In Asia, a 7 to 10 litre bin is sufficient for a daily collection for the domestic wastes of a family of 6. Bins having a capacity of 20 to 30 litres are suitable for collection twice a week. Furthermore, generation rate also determines the size of a container. Bigger bins are recommended in densely populated areas because the generation rate is high.

4. Activity of the people. People's activities greatly affect the generation rate. During summer and holidays, more wastes are generated, thus more frequent collection is desirable.

5. The weight of the contents of the bins must also the taken into account. It is economical to collect heavy wastes 3 times a week because 1 man needs assistance to lift the container, therefore an additional crew member is needed.

The cost/tonne rises rapidly as frequency of collection is increased. Therefore, weight in the container should be considered because the greater the frequency, the less weight collected and the higher is the cost/tonne.

In summary, communal storage sites should be cleared daily or at least 3 times weekly. For dwellings with gardens and buildings having outside storage space a twice weekly collection is adequate provided a closed portable container is used. In the case of homes and buildings that lack outside storage sites, collection should be made daily, unless communal containers are provided. Because frequent collection appears to imply high costs, unconventional systems and transport methods may have to be employed to bring expenditure within local capacity.

TRANSPORTATION OF SOLID WASTES IN ASIA

As already mentioned, vehicular collection is widely used throughout the world, and pneumatic and hydraulic systems are still in their experimental stage. In developing countries, these pipeline collection systems cannot compete economically with the vehicular system because of their sophistication. The following discussion will be limited to solid waste collection by vehicles.

The major components of vehicular collection are: the trucks, the crews and, sometimes, transfer stations. Types and sizes of refuse storage containers, crew sizes, types of trucks used and the scheduling, method of pick-up and the location and organisation of transfer stations or disposal sites are the major considerations in the efficiency of collection. This has been discussed earlier.

Refuse Collection Vehicles

Refuse collection is the process of transferring solid wastes from the storage receptacle to the place of disposal. Essentially this involves emptying the storage container into a vehicle in which the wastes are transported, but it is possible to organise this service in many different ways and to employ transport methods ranging from handcarts to 30-tonne vehicles. Refuse collection is a very costly service and every city should evaluate both vehicles and methods in order to find the system which is most appropriate to local conditions in terms of quality of service and cost of operation.

Collection vehicles must be designed in such a way to meet the needs of Asian developing countries. The following remarks are applicable to vehicles of all types:

- the load should be covered during transport; this is imperative for motor vehicles travelling at 30 kph or more, less important for very slow moving vehicles;

- the loading height of vehicles receiving the contents of manually emptied containers should not exceed 1.6 metres;

- unless the load is carried in portable containers, the body of a vehicle should have hand-operated or power-operated tipping gear, or a power-operated ejection plate;

- the transfer of wastes from a primary collection vehicle to a larger vehicle should never involve dumping the load on the ground and both vehicle designs should take account of this;

- there are many situations in which the most suitable vehicle will be a handcart or one drawn by an animal; these vehicles should receive the same standards of mechanical design as motor vehicles, particularly as to ball or roller bearings for wheels, and rubber or pneumatic tyres.

The truck age plays an important role in the efficiency of solid waste collection. It is obvious that old vehicles offer a poor service. And the maintainance cost of old vehicles, say 8 years old or more, is much greater than the cost of a replacement. Thus, to achieve maximum deployment of vehicle, it will be economical to schedule vehicle replacement on a regular basis utilising a sinking fund financing system. The following is a kind of catalogue of refuse vehicle types used in Asia.

Handcarts

In Europe, handcarts are used for street sweeping because they cause minimal obstruction and their capacity is enough to keep a sweeper busy for at least 2 hours. Handcarts are also used in parts of Asia for daily house-to-house collection, especially in very narrow streets inaccessible to motor vehicles.

The problem in Asia is that handcarts are of a fixed design; containers are not removable. Much of the labour is wasted and vehicle standing-time is increased because handcarts are open boxes, and the only way of transferring the wastes to motor vehicle is to dump them on the ground and a shovel or a basket is used for reloading.

The most important aspect to be considered in the handcart system is the design. It should ensure that the load is carried in a number of containers which can be lifted off the cart and emptied directly into a larger vehicle. Fig. 3 shows the different design of handcarts. In Mexico handcarts consist of a platform supported by 4 small wheels and carrying 2 200-1 (oil) drums. For daily house-to-house collection of refuse house-to-house, one 6 bin handcart load equivalent to about 50 dwellings at 8 litres/dwelling/day, can be used, and one collector would be able to serve from 200 to 300 dwellings/day.

Tricycles

Pedal tricycles with a box carrier in front are common in Asia. They can be adopted to carry wastes, but their volumetric capacity is less than a handcart. They were used in Saigon by self-employed refuse collectors who served about 200 dwellings/day.

The two stroke, three-wheel motor cycle is in common use in several cities in Asia and West Asia. It can be fitted with a high level tipping body of about 2 m^3 capacity while retaining a low loading line (Fig. 4). Its relative high speed gives it an operating radius of about 10 km.

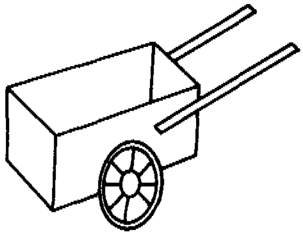
Tractors and Trailers

Agricultural tractors are widely available in Asian developing countries. The main advantages of this kind of transport of solid wastes is in the maintenance facilities which are more readily available than for most other types of vehicle. Together with a trailer, the capital cost of tractor may be more attractive than a 5 tonnes truck. Another advantage is that it has a power take off from which hydraulic tipping gear on a trailer can be operated (Fig. 5).

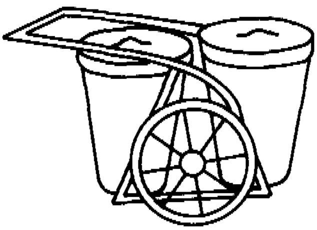
The tractor offers the cheapest method of motor transport for solid wastes up to a trailer capacity of about 6 m^3. The agricultural tractor and trailer is often used as a continuously coupled unit for the collection of refuse from houses or communal storage points, but it also has great potential as transfer unit because of the ease with which the prime mover and the "body" can be separated.

Tonne-Truck

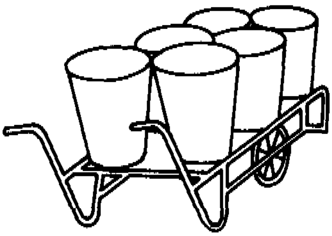
This is a type of vehicle widely used for the collection of wastes



Handcart with box body, a type widely used in Asia by sweepers and sometimes for refuse collection. Capacity from 200-500 litres. Emptied by dumping contents on the ground.



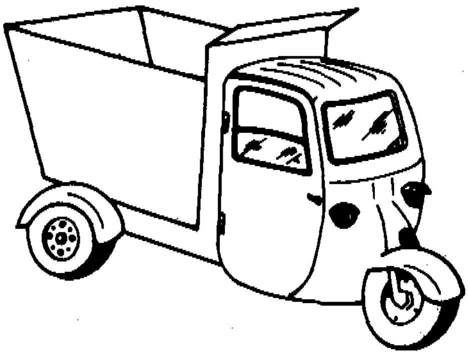
Two-bin handcart in general use throughout Europe by sweepers, total capacity 120-200 litres according to bin size. The bins are emptied directly into a transfer facility.



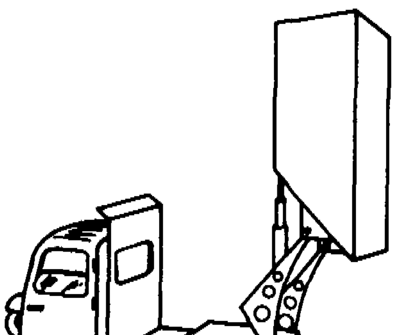
Six-bin handcart suitable for daily collection of domestic wastes where generation is low. The total capacity can be from 300-500 litres. Bins emptied directly into a transfer facility. Handcarts of this type have been used in Britain for collection of kitchen waste separately for conversion to animal feed.

Fig. 3. Different Designs of Handcarts

(Source: FLINTOFF, 1976)

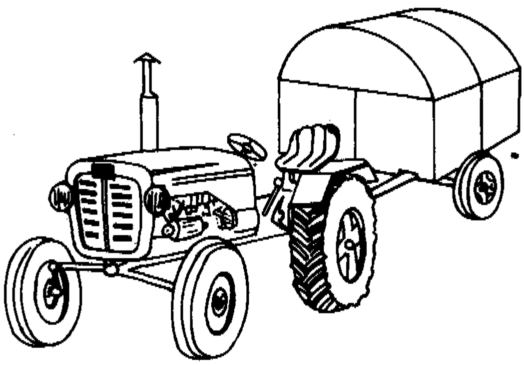


Body capacity about $2m^3$



The hydraulic tipping gear is cleverly designed to permit discharge at about 1.5 metres above ground level-direct into a transfer facility. This could be the hopper of a compactor vehicle, or a skip

Fig. 4. Lightweight Motor Tricycle



An agricultural mini-tractor can tow a 3 m^3 side-loading trailer with sliding shutters. Hydraulic tipping gear is operated by a power take-off.

A bullock could be used to tow a trailer of this design. If hand-operated, a worm and nut tipping gear would be substituted for hydraulic.

Fig. 5. Agricultural Tractor

from communal sites. It is desirable that a refuse collection vehicle should have at least 2 m^3/tonne of rate carrying capacity and a loading height not exceeding 1.6 m. An open body truck with 8 m^3 capacity is commonly used in many Asian countries. It has a low loading height and equipped with tipping gear. Due to its open body type, odours are easily detected during traffic snarls, and light materials such as paper can easily be blown. This type of vehicle does good job for long distance hauling.

Barrier-Loader

The barrier-loader has a van-type body, loaded from the rear. Hanging from roof-fixed rails is a movable barrier which extends across the body to a height of 1.6 m above the floor (Fig. 6). The contents are discharged by hydraulic tipping gear, the barrier swinging clear during this operation. Barrier-loader with a density of 300 kg/m^3 is common in many Asian developing nations.

Fore and Aft Tipper

Its main feature is that the body can be tipped 2 ways: towards the rear for unloading and towards the front for the transfer of wastes loaded at the rear to the front end of the body (Fig. 7). Body capacities of about 12 m^3 are normal with this type of vehicle. It represents halfway stage towards compactor vehicles and is suitable for densities from 250 kg/m^3 upward.

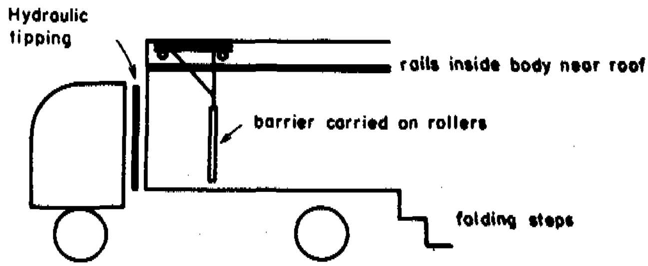
Container-Hoist

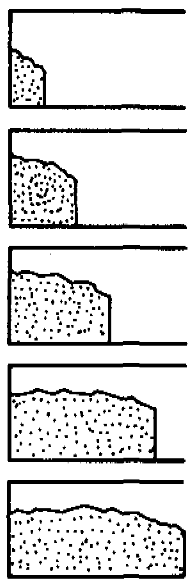
This vehicle with 5-10 tonne range is equipped with a pair of hydraulically-operated lifting arms which are used to lift a detachable body on or off the flat floor of the vehicle. The detachable body is a metal box (skip) having a capacity from 3 m^3 upwards.

The container-hoist vehicle is an alternative to tractor-trailer units and has the following advantages: a skip is much cheaper than a trailer, it is much less liable to damage by fire, vandalism or loss by theft than a trailer; the speed of a container vehicle is much higher than of agricultural tractor. The disadvantages are: the cost of a container vehicle is double that of an agricultural tractor; in many cases it transports a lesser weight than a tractor-trailer. It is recommended that Asian developing countries should have skip systems based on capacities not less than 4 m^3.

Animal Carts

Another common collection vehicle widely used in Asia for refuse collection is the animal-pulled cart. Horses, buffalos, and bullocks are still used in many parts of the world for house-to-house collection, especially in areas which are not densely populated. The average capacity of draught animal carts ranges from 2-4 m^3 and they are often



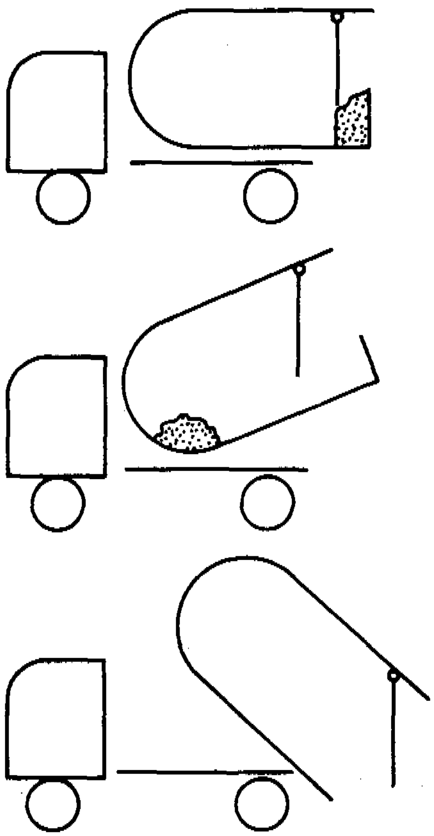


STAGES IN FILLING VEHICLE

Collectors walk inside and empty bins over barrier. Barrier is moved manually towards the rear when available space has been filled.

For high density wastes the barrier loader achieves a similar result to the compactor vehicle without employing costly hydraulic mechanisms, but it is more labour-intensive as the collectors have to walk inside the vehicle.

Fig. 6. Barrier Loader



swinging baffle plate
rear loading space

When rear space is full, the body is tipped forwards to transfer wastes to the front end.

The baffle plate prevents wastes from falling towards the rear when the body is returned to horizontal.

The load is discharged by normal tipping to the rear.

For high density wastes the fore-and-aft tipper performs similarly to a compactor, but with a simpler mechanism. The operator must be careful not to elevate the body in a street with overhead power lines.

Fig. 7. Fore-and-aft Tipper

equipped with tipping gear. The tipping body is operated by pivoting the body or the use of a manually operated worm and nut.

Animal carts operate from a two-level transfer station: first, the animal carts tip their loads directly into a large motor vehicle and then this motor vehicle will transport the solid wastes to the disposal sites. This mode is successfully applied in Madras using bullocks. But if the distance from the disposal site to the source is great, this system will not work efficiently. Animal draught carts have an effective radius of operation of about 3 km.

The advantages of animal-pulled carts are no consumption of fossil fuels; almost silent operation and that the driver can leave the vehicle and assist in loading; and low cost compared with motor vehicles.

Collection Crews

Crew Size

Crews numbering 2 to 8 are used for collection from communal storage sites, kerbside and door-to-door collection.

In the case of collection from masonry enclosure (0.5-5 tonnes of wastes), the limit on crew size is imposed only by the number of men who can simultaneously empty a basket into the vehicle. It is customary to employ about 6 men under these conditions.

Where cylindrical concrete bins are used, the number of men who can work simultaneously transferring wastes from bins to baskets is limited by the small diameter of the bin. Usually, 1 or 2 men can work at the same time. The maximum useful crew size is 2 men when 200-litre drums are placed at intervals on the footway or verge. In the case of block collection, it is never necessary to employ more than 2 men as their only task is to stand at the rear of the vehicle and empty bins handed to them by residents.

For door-to-door and kerbside collection systems, the choice of the most economic crew size is more complex. The main factor is that the greater the crew size the longer the distance over which the crew is spread at any one time; but the vehicle can be in only one place. Thus the larger the crew the more time will be spent waiting with a bin for the vehicle to come within reasonable distance, or walking towards the vehicle.

Time Study

For every situation there is an optimum crew size which achieves the lowest total cost of labour and vehicle. In most cities it is possible to define several different types of areas, the physical constructions of which vary sufficiently to demand different crew sizes.

Relative vehicle and labour costs are usually constant for a city, but may vary within a country, and worldwide they vary considerably. For these reasons it is necessary to carry out time studies in every city in order to determine optimum crew size for typical areas. The route should be long enough to provide work for between 1 and 2 hours. The total number of bins emptied and elapsed time between the starting and finishing points will be recorded.

FLINTOFF (1976) reported the following results of door-to-door collection for an area of detaching houses:

Crew Number	Bins/man/hour	Bins/crew/hour
2	30	60
4	25	100
6	22	132
8	19	152

This clearly shows the decline in labour productivity which occurs with each additional labour increment; that decline is, however, accompanied by rising vehicle productivity which is proportional to the number of bins emptied/team/hour.

Relative Labour and Vehicle Costs

To determine optimum crew size, FLINTOFF (1976) applied unit cost labour and the vehicle. To do this, the imaginary currency called "money units" has been used and the performances above are described in Figs. 8 and 9. It can be seen that for a low ratio of wage rate to vehicle cost, 1:10, the largest team achieves the lowest cost; and for a high ratio of wage rate to vehicle cost, 1:2, a small team achieves the lowest cost.

Relay Systems

As a rule of thumb, when the time required to deliver a load to disposal and return to the working area is approximately equal to the time required to load a vehicle, then a 2:1 relay, i.e. 2 vehicles to 1 crewman (Fig. 10), enables the crew to be continuously employed throughout the working day. When transport time is approximately half of the time required to collect a full load, a 3:2 relay can be used (Fig. 10).

Relay working achieves maximum labour productivity but some of this advantage is lost by a reduction in output towards the end of the day as a result of fatigue. Crews working with a single vehicle benefit by rest periods between loads and this is reflected in a higher average rate of working during the smaller number of hours during they are effectively employed.

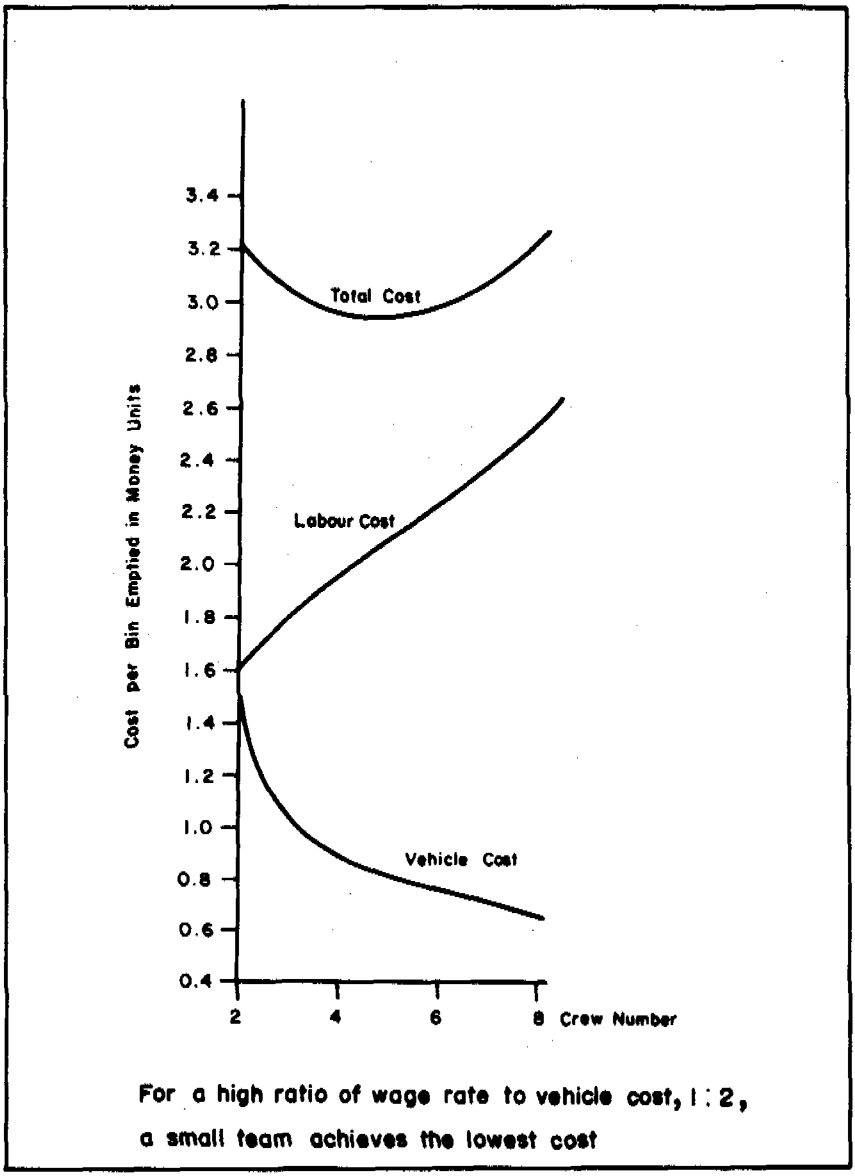
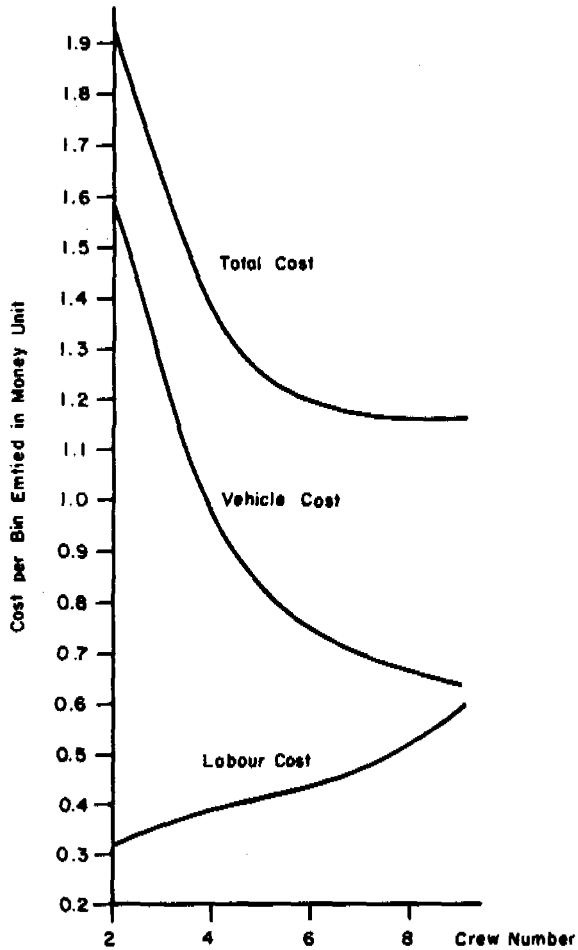


Fig. 8. Determination of Crew Size
(Crew Collection, Door-to-Door,
Wage to Vehicle Cost, 1:10)



For a low ratio of wage rate to vehicle cost, 1 : 10, the largest team achieves the lowest cost

Fig. 9. *Determination of Crew Size*
(Crew Collection, Door-to-Door, Wage to Vehicle Cost, 1:2)

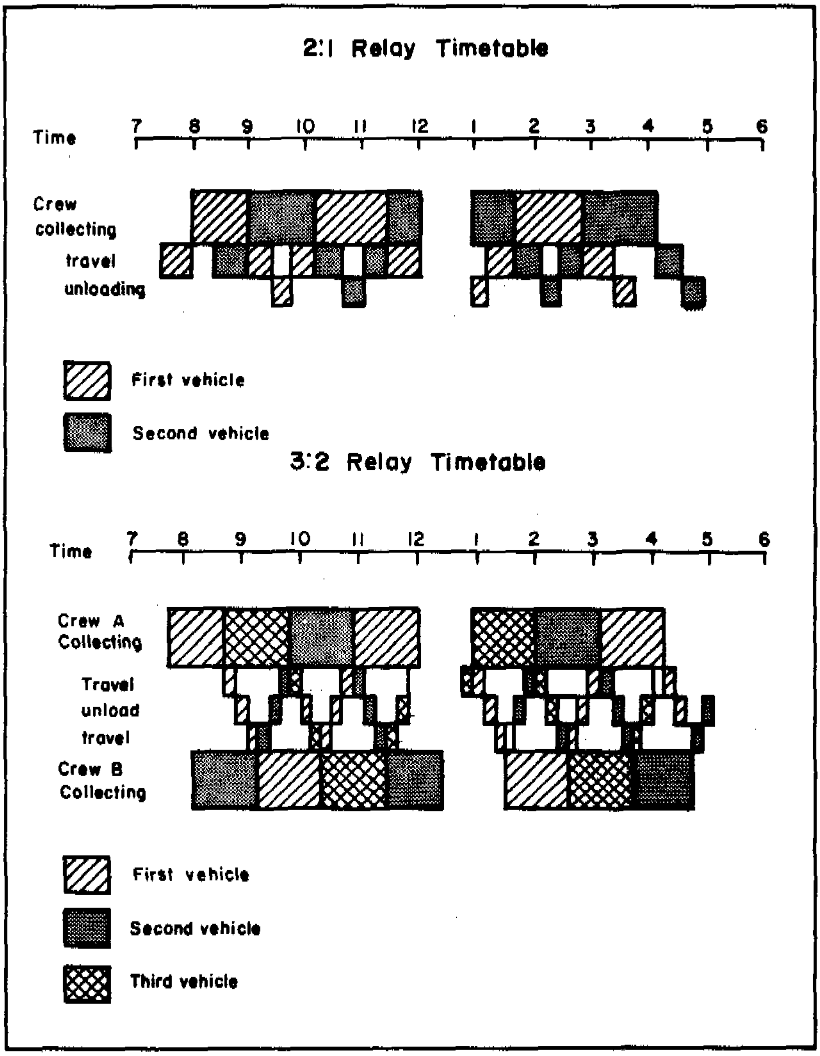


Fig. 10. Relay System

One advantage of relay systems is that in the event of a sudden breakdown of one vehicle, work can proceed using a single vehicle and by working overtime the day's task can be completed; it helps, therefore, in maintaining reliability of the service. However, relay systems require a high standard of supervision and discipline.

Transfer Stations

In places where the distance between the collection area and disposal site is very far, it may be cheaper to use transfer stations within the city and transport the wastes in bulk to the disposal site with or without pre-treatment. By reducing the time spent by collection vehicle travelling to and from the disposal point, transfer stations become more productive and offer more continuous work for the loaders without the need for a relay system. The greater the capacity of the collection vehicle the lower the unit transport costs and fewer journeys it has to make each day to and from disposal point. The other consideration as to whether a transfer station is needed is to cut down long haulage. It seems economical to have a transfer station at the centroid of a collection area, but this practice is not possible. It is advisable to have a transfer station as near as possible. Another reason for doing this is because the salvaged materials need not be transported back to the city (a long haul). Economy of scale is very important in any type of system. Undoubtedly, a transfer station reduces the total collection cost. Sometimes the cost of the salvaging operation is also included under the cost of the transfer station, which should not be done. Actually, salvage operation cost is part of the collection cost.

Street Cleaning

Street sweeping is an important function in the collection process. Between a third and a half of the solid wastes collection budget is spent on street sweeping. Sometimes its cost is much higher than the cost of collection. In India, for example, where street sweepers are employed, in 1974 it is estimated that about Rs. 31,000,000 (US$3,900,000) was spent in sweeping, while only Rs.7,330,000 (US$920,000) was spent in collection.

Shortcomings in public behaviour is the main source of street wastes. People throw litter anywhere and not in the containers provided. Residents often do not dispose of their wastes on the communal storage dump because it is far away and instead, just dispose of their garbage on the street or in vacant places nearby. However, in some cities, a high proportion of street wastes arises from deficiencies in the refuse collection services and vehicles.

The major equipment used in sweeping is the broom. Normally brooms have long handles to permit sweepers to work in an upright position. Metro Manila has about 4,000 sweepers equally distributed in every zone, equipped with long, stiff, bristle brooms. Stiff bristle brooms are very useful for paved surfaces and to remove dirt from crevices. In unpaved surfaces, soft brooms are used. Soft brooms are widely used in tropical and sub-tropical countries because they are cheap and can be manufactured using local fibre. The only objection to soft brooms is they do not remove heavy fine wastes.

In lifting the gathered wastes into the receptacle, a shovel is used, flat front shovels being the most efficient ones. The problem with the shovel is that it cannot effectively transfer light waste materials like leaves, papers, etc.

Handcarts are used in transporting these street wastes to the main storage container. They are the most convenient transport system for street sweeping purposes. The aim of street sweeping is to reduce to a minimum the proportion of time spent on transport and increase the time spent on sweeping. Baskets are used in Asia for transport. As a result more time is spent in walking than in sweeping. If individual sweepers are provided with simple but sturdy handcarts capable of transporting removable containers of about 100-200 litres capacity, they can efficiently operate within a 1 km radius from a transfer site where a trailer can be parked for haulage.

PROBLEMS OF THE PRESENT REFUSE COLLECTION SYSTEM IN ASIA

Most domestic storage methods used are not standardised so collection is difficult and costly. Usually, residents dump their wastes into the communal bins provided. The contents of each communal storage site are removed by a collection team every 2 or 3 days. But the problem is in the design of most communal storage which encourages the breeding of flies and rodents so the health hazard is high.

However, in some Asian cities where bins are widely spaced, private collectors visit every house, hotels, etc. at regular intervals of 2 or 3 days to collect the waste. They disposed of the wastes either to transfer stations if any or to the disposal site. But if the private collector fails to collect the wastes on the scheduled day, residents usually resort to unofficial dumping - in canals, on the pavement or in vacant areas nearby.

This bad habit is the main reason why most of the methods used in collection and storage fail. They seem to be indifferent to the system. They don't co-operate with the authority in the implementation of the method and yet make most of the complaints about the inefficiency of the refuse collection services.

Health

The major problem associated with the present storage and collection system in Asia is the health hazard. Health officers have found that great risks extend to the health of workers and indirectly endangers the health of the public and animals as well.

The methods of removing wastes from communal storage sites and from domestic storage bins involve direct body contact by workers with the wastes. The squatting and stooping positions result in the inhalation of contaminated dust and droplets. It also involves soiling of the hands, arms and feet of the collectors. Studies show that most collectors exposed to this system suffer a higher than normal incidence of intestinal diseases.

The observed risks to public health are indirect ones. They arise only when insects and rodents have free access to the wastes. These insects and rodents are disease vectors and can transmit diseases to human beings.

The only way that public health can be safeguarded is to cover the containers and see that they be kept closed all the time. The frequency of collection should be intervals shorter than the lifecycle of insect vectors. A direct risk may occur but this is seldom and caused by inhaling contaminated dust and droplets when passing an uncovered bin. Not only people but also animals - pigs, dogs, cattle, etc. turning over the waste containers searching for food may be infected with various diseases.

Effect on Environment

The present methods used in solid waste management produce considerable environmental impact. Open vehicles used in transporting the collected wastes, a dirty and dusty loading process, open storage in which scavengers and animals can have free access and sort out the wastes will lead to environmental degradation. Often, this is characterised by visual offensiveness and the scattering of dust and litter.

Improper management can aggravate the water pollution problem. Water pollution arises from the leachate in sanitary landfill which carries contaminants from the wastes and will come in contact with the underground water, river and lakes.

Deficiencies in Techniques and Management

Most of these problems could be avoided if the techniques and management were efficient, such as the use of better equipment such as long-handled stiff brooms, large hand-trucks, portable containers, etc. which will double labour productivity. To increase vehicle productivity, vehicles should be equipped with tipping gear to avoid loss of manual loading.

Almost all of the Asian cities lack a network of district depots to serve as polling points, offices for district supervisors and transfer points for wastes collected in small vehicles. Usually, the solid waste management organisation of one city/municipality is incorporated in its health and sanitation unit, so, its function is limited in the light of the policy of the head unit. Middle management tends to be weak due to lack of qualified and professional personnel and the lack of training facilities for solid waste management technicians. Presently, there is a great demand for professional engineers to monitor vehicle and plant maintainance, landfill planning and supervision.

Constraints

The solution to these problems can be sought but is limited by a number of constraints. These constraints include dense traffic, too narrow lanes for motor vehicles, lack of public interest, shortage of public funds, lack of foreign exchange, climatic vagaries and social and religious customs.

Most important is public funds. If the fund is not enough, it can be expected that the refuse collection service will be poor. Money dictates the kind of service the community can have.

In Asia, the wage rates are low so manual labour can be sustained. Unreliable service is due to vehicle shortage or very old vehicles. The acquisition of vehicles is very difficult. The GNP of most Asian countries is low, and not sufficient to buy enough new vehicles. Also, foreign exchange is limited and is required for more important services.

Social and religious customs also affect the search for a solution. Sometimes they become worse factors. Some families live in crowded conditions in one room so there is no more space for refuse storage; and under some religions the storage of refuse within the dwelling is considered taboo.

ACKNOWLEDGEMENT

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REFERENCES

BARNES, R.M. (1968) Motion and Time Study, Design and Measurement of Work, John Wiley & Sons, New York.

CLARK, R.M. and HELMS, B.P. (1970) Decentralized Solid Wastes Collection Faculty, J. San. Eng. Div., ASCE, V. 96, No. SA5, pp. 1035-1043.

FLINTOFF, F. (1976) Management of Solid Wastes in Developing Countries, WHO Regional Publications, Southeast Asia Series No. 1, WHO New Delhi.

HARDLEY, G. (1963) Linear Programming, Addision Wesley Reading, Mass.

HIELLIER, F. and LIEBERMANN, G. (1967) Introduction to Operation Research, Macmillan Book Co., New York.

OUANO, E.A.R. and FRANKEL, R.J. (1974), Decision Criteria in Solid Wastes Collection Operation, to be published in J. Environmental Eng. Div., ASCE.

OUANO, E.A.R. and PESCOD, M.B. Matching Solid Waste Collection Technology to Local Capability, Proceedings, W.H.O. Regional Seminar on Solid Wastes Management, Bangkok, Thailand, 29 October - 7 November, 1974.

PESCOD, M.B. (1975) Solid Waste Management, Course on Environmental Aspects of Development, U.N. Asian Institute for Economic Development and Planning, Bangkok, Thailand.

QUON, J.E., CHARNES, A. and WERSAN, S.J. (1965) Simulation and Analysis of 2 Refuse Collection System, J. San. Eng. Div., ASCE, V. 91, No. SA5, pp. 17-36.

QUON, J.E., MARTINS, R.R., and TANAKA, M. (1969) Efficiency of Refuse Collection Crews, J. San. Eng. Div., ASCE, V. 96, No. SA2, pp. 437-453.

STONE, R. (1969) A Study of Solid Waste Collection System Comparing One-Man Crew with Multi-Man Crews, U.S.P.H.S., Bureau of Solid Wastes Management, Washington, D.C.

SANITARY LANDFILL: A GENERAL REVIEW AND PROBLEMS IN ASIA

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INTRODUCTION

Human beings, at all levels of development, produce domestic wastes; which at the least comprise kitchen wastes, ashes, worn out clothing etc. The industrial revolution in the temperate countries concentrated people in urban areas of very high population density and added new sources of wastes: shops, institutions and factories. New problems like high-rise buildings, supermarkets, industrial wastes of many kinds have arisen. Thus in those countries where industrialisation came early, services for the regular removal of domestic and trade wastes have been in operation for a long time.

Many developing countries are suffering the problems of urbanisation. This sometimes exceeds the densities of western cities, and is aggravated by the fact the region is lacking the proper financial resources needed to provide solutions of the western type (FLINTOFF). The developing countries are not unaware of the importance of avoiding environmental pollution, which shadowed urbanisation and industrialisation in Europe and North America.

The technical literature of the West may be of little value for the success of solid waste disposal, because of too many climatic, economic and social differences. Therefore the aim in developing countries must not be to mimic the technology of industrialised countries, but rather to employ the technology appropriate to their own situations, with the primary idea of meeting the needs of public health.

Our polluted environment has been the object of increasing concern. It is only in the recent past that solid waste, which has been called the third pollution, has received the true attention at the international level. Public apathy toward the disposal of solid waste is no longer commonplace. In many of the developing countries, the public is rejecting the traditional open burning dump. Citizens are recognising the need for safe and sanitary management of solid wastes. Demand increases for properly engineered, effective, and economic solid waste disposal facilities.

The production of solid wastes is increasing constantly, due not only to an increasing population but also to a higher per capita rate of waste generation. With the use of various methods of resource conservation, including reclamation and recycling and of volume reduction etc., it might appear that proper design and operation of the sanitary landfill would become less important. In fact, however, this method of disposal will always be necessary, even with the most rigorous methods of processing and recycling.

Open and burning dumps, which are all too common, contribute to water and air pollution and provide food, harbourage, and breeding grounds for insects, birds, rodents, and other carriers of disease (WEISS, 1974). An acceptable alternative to the present poor practices of land disposal is sanitary landfill.

Sanitary landfilling may be defined as engineered method of disposal of solid waste on land in manner that protects the environment, by spreading the waste in thin layers, compacting it to the smallest practical volume, and covering it with compacted soil by the end of each working day or, if necessary, more frequently (A.S.C.E.,1976).

Sanitary landfilling is a method of refuse disposal, which confers environmental improvement by restoring natural contours. Sanitary landfill is usually by far the cheapest method of refuse disposal. Hence it is adopted all over the world.

Decomposition in a sanitary landfill arises from chemical changes, which are brought about by bacteria (FLINTOFF). The consequences of all these complex changes include temperature changes within the landfill, the production of gases and the production of soluble and particulate and decomposition products.

SELECTION OF SITE

The selection of a suitable site or sites for sanitary landfill requires the consideration of many factors. Some of these can be measurable, while some are subjective or need value judgements. Considerable preliminary information can be obtained, including aerial photos, land use plans, well logs, soil surveys, geological surveys and climatological data.

Most site selection factors fall in two categories consisting of public attitudes and technical aspects.

A balance of technical and public relations factors is necessary in order to ensure success. The only means of ensuring that the job is done right is to conduct an organised and comprehensive site selection study.

The major criteria of site selection are the protection of health and safety, the prevention of pollution and environmental damange, the economics of operation and public and political acceptability.

Where several possible sites are being compared, a scoring system with suitable weightings reflecting the relative importance of various factors is used. This is particularly useful where subjective non-engineering judgements are involved. Its virtue is that it demands an orderly and rational process of comparison. (See Table 2.)

Land Requirements

The land area, or more important, the volume of space required, is primarily dependent upon the character and quantity of the solid wastes, the effeciency of compaction of wastes, the depth of the fill, and the desired life of landfill. In estimating volume requirements, volume reduction of solid wastes due to compaction must also be considered. As an estimate, a population of 10,000 people, with a solid waste generation rate of 2.406 kg (5.3 pounds) per person per day, and density of 593 kgs per metre^3 (1000 pounds per yard^3), and 1 part earth cover to 4 parts waste, the space required would be 18,450 metre^3 (15 acre feet) per year. (SORG and HICKMAN, 1970).

The site should be as close as possible to the built-up city in order to reduce transport costs. Sites will be preferred at which the nearest dwelling is at least 200 metres distant. The roads to the site should be of width and construction adequate to handle all sizes of trucks when fully loaded and during all weather conditions.

Drainage control is an important element in site operation. The site must be carefully designed to be free-draining both during the operation and after completion. Areas upstream of the site, which might naturally drain across the face of the landfill must be diverted around the new fill, while areas downstream must be capable of carrying the additional flow. Contour maps of the area are vital for this purpose, which can be available at the concerned geological survey offices.

Suitable Soil Characteristics

Soil is important to landfill design for 2 reasons:

Interface : This is generally the material which lies between the completed landfill and the ground water system

Cover : This is the material used to cover the landfill daily and also the final cover

Since soil used as interface deals with the deeper layers of soils, little data can be obtained from a visual inspection of the site. The data from a soil conservation survey will be the chief source though soil information at depth is only available by interference. Borehole examination of a tentatively selected site is imperative in order to determine interface conditions.

For soil used as cover, the field investigation of the potential site should include a soil analysis to determine the suitability and quantity of soil available for cover material. Texture provides by far the best indication as to the value of a site. Variations in the distribution of the 3 primary constituents, sand, silt and clay, and the general terminology for soil type are shown in Figure 1.

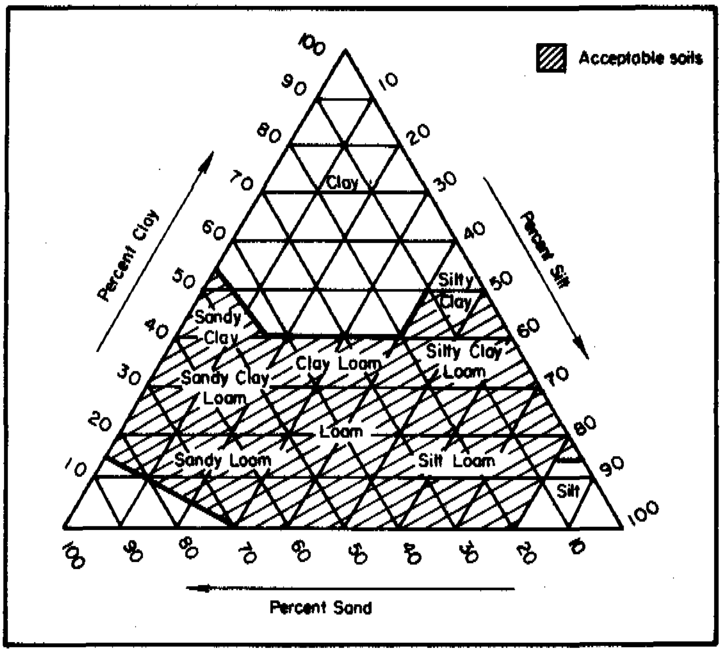


Fig. 1. Ternary Diagram Showing Soils Suitable for Cover Material.

In general, soil with good workability and compaction characteristics is the most desirable cover material. Loams and mixed loams have been determined to be the best cover material. On balance a wide range of soils may be used as cover materials provided the appropriate precautions are taken. The soils suitable are given in Fig. 1 (NOBLE, 1976).

Depth of Water Table

The water table should be as deep as possible at a potential site. The field officers of the area may be in a position to given the information. Water well users in the area can also provide valuable assistance. Ultimately the depth to water table will determine the life of the fill. The more the depth of water table the larger is the life (NOBLE, 1976). The cross section in Fig. 2 gives this idea clearly.

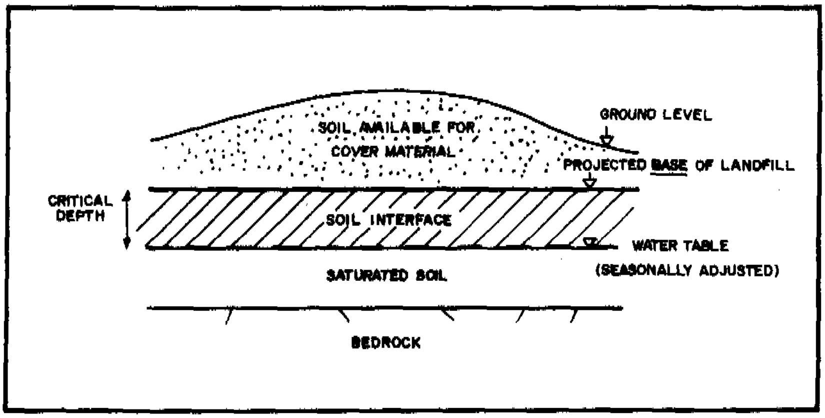


Fig. 2. Soil Interface Diagram.

Other Factors

The haul distance is an important economic factor in selecting the site. The economic distance to the site will vary from locality to locality depending upon capacity of collection vehicles, haulage time and size and methods of collection agency.

The stratigraphy and structure and the physical and chemical properties of the underlying geologic formation should be determined from existing geologic mapping and records and additional site investigation to assess the risk of ground water contamination by leachate, the location of the zone of saturation must be determined, and also the quality, rate of flow, and the direction of flow of ground water through the aquifer. These will be dependent on the permeability of the strata and hydraulic gradient.

In areas receiving considerable rainfall, a low-lying site may be undesirable because of flooding and muddy conditions. In windy locales, a site surrounded by natural windbreaks will help to contain loose paper and minimise dust problems. In an extremely cold locality, a site requiring excavation of trenches and cover material may become a problem because of freezing during the winter months. In rainy areas a desirable site would be high in relation to the surrounding area and have good drainage features.

Topography will influence many things (A.S.C.E., 1976). The drainage pattern in the area, present and future land use, ground water contour, method of working the site and the access to it. Whenever possible, flood-plain land should be avoided entirely. Sites located near rivers, streams or lakes also deserve careful scrutiny. Special attention should be given to low-lying sites that might be drainage basins for surrounding areas.

Cost Considerations

Road construction, site preparation and clearing prior to operation, and restoration for final land use can be expensive and affect site selection. In this connection, the size of the operation is important. Thus for a given community, 1 large site is preferable to 2 or more smaller sites, other considerations being equal.

Normal development costs would include diversion of surface runoff, clearing, grading, extension of electricity, water, telephone, access roads, fencing, scales, offices and other buildings. In planning the system, the economic life of various components must be estimated.

Another major cost factor for a site is related to the depth and characteristics of the soil and its suitability as cover material. Its unsuitability for any of these functions may mean extra costs in providing alternative measures. Table 1 serves as a guide for assessing the general suitability of soil as cover material (A.S.C.E., 1976).

Table 1. Suitability of General Soil Types as Cover Material

Function	Clean gravel	Clayey-Silty gravel	Clean sand	Clayey-Silty sand	Silt	Clay
Prevent rodents from burrowing or tunneling	G	F-G	G	P	P	P
Keep flies from emerging	P	F	P	G	G	E[a]
Minimise moisture entering fill	P	F-G	P	G-E	G-E	E[a]
Minimise landfill gas venting through cover	P	F-G	P	G-E	G-E	E[a]
Provide pleasing appearance and control blowing paper	E	E	E	E	E	E
Grow vegetation	P	G	P-F	E	G-E	F-G
Be permeable for venting decomposition gas[b]	E	P	G	P	P	P

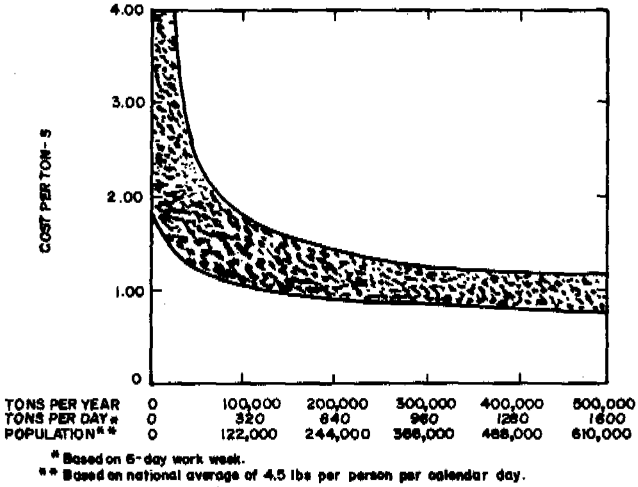
[a]Except when cracks extend through the entire cover.

[b]Only if well drained

Note: E = Excellent, G = good, F = fair, P = poor
(Source: Brunner, D.R., et al., 1971)

Haul distance is also a major factor in estimating and comparing costs of various sites. The economics of transfer stations can also be considered if the haul distance is too long. The measures necessary to protect ground water or surface water supplies and the estimated cost of such measures should be considered. The leachate problem should be assessed, and the measures necessary to intercept, collect and treat it must be taken into the cost evaluation. Similary the cost of controlling the gases must be evaluated.

The operating cost of a small operation handling less than 50,000 tonnes per year varies from $1.25 to $5.00 per tonne, as shown in Fig. 3. This wide range is due to the low efficiency of smaller operations.



Source: PB 204, 403, EPA, 1970

Fig. 3. Sanitary Landfill Operating Costs.

Decision Table for Landfill Site Selection

In summary, the chief criteria for finding a site can be presented in the form of a table to assist in making the final selection (NOBLE, 1976). This way all the possible sites can be evaluated and appropriate site selected. A comparative scoring system (as mentioned in this section earlier) should be used (Table 2).

SITE INVESTIGATION

When the site selection process yields good results, a detailed site investigation is necessary. The first basic requirement is a more detailed knowledge of soils and geology. A borehole examination gives basic information about the site, and sub-surface cross sections can be drawn with reasonable assurance of accuracy. Figs. 4 and 5 provide an excellent example of a well-researched landfill site with excellent detail in the cross sectional diagram. (NOBLE, 1976).

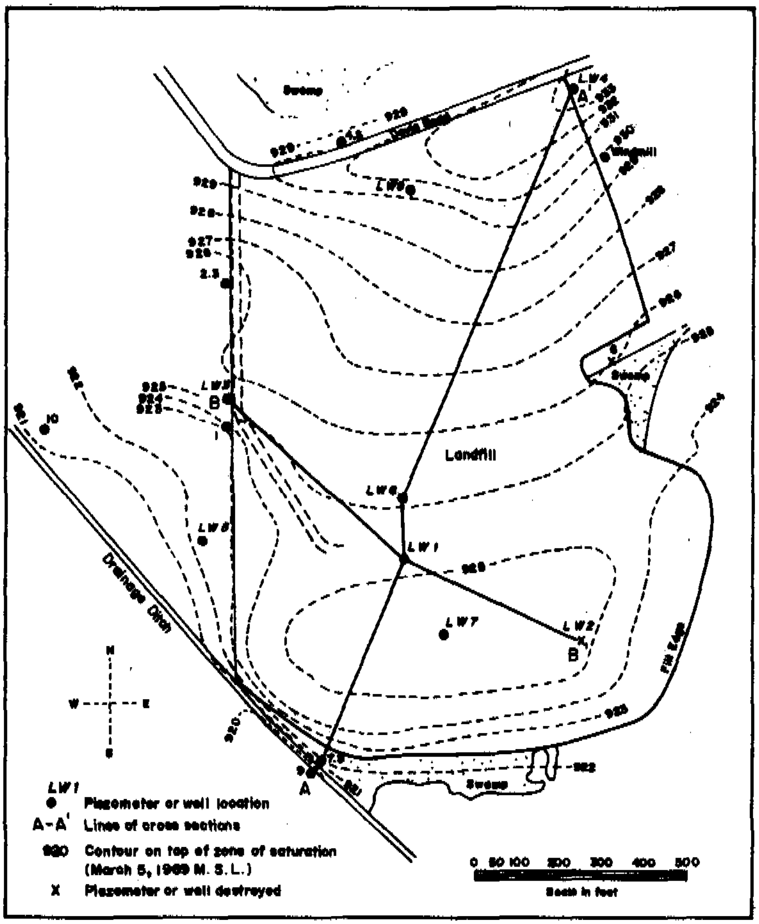


Fig. 4. A good example of a well cross-sectioned landfill. Plan view of the Woodstock landfill and surrounding area, showing locations of borings and the contours of the top of the zone of saturation. Gradients are away from the upland of the northern part of the landfill in all directions. In the older part of the filled area, the gradient is southward to swampy areas bordering the landfill or to the drainage ditch west and southwest of the landfill. Some influence of the landfill is shown by a steepening of gradients on the southern edge. This steepening suggests that a small ground water mound lies beneath the landfill.

Source: "Hydrogeology of Solid Waste Disposal Sites in Northeastern Illinois", by G.M. HUGHES, R.A. LANDON and R.N. FARVOLDEN of the Illinois State Geological Survey. Published by the U.S. EPA, 1971.

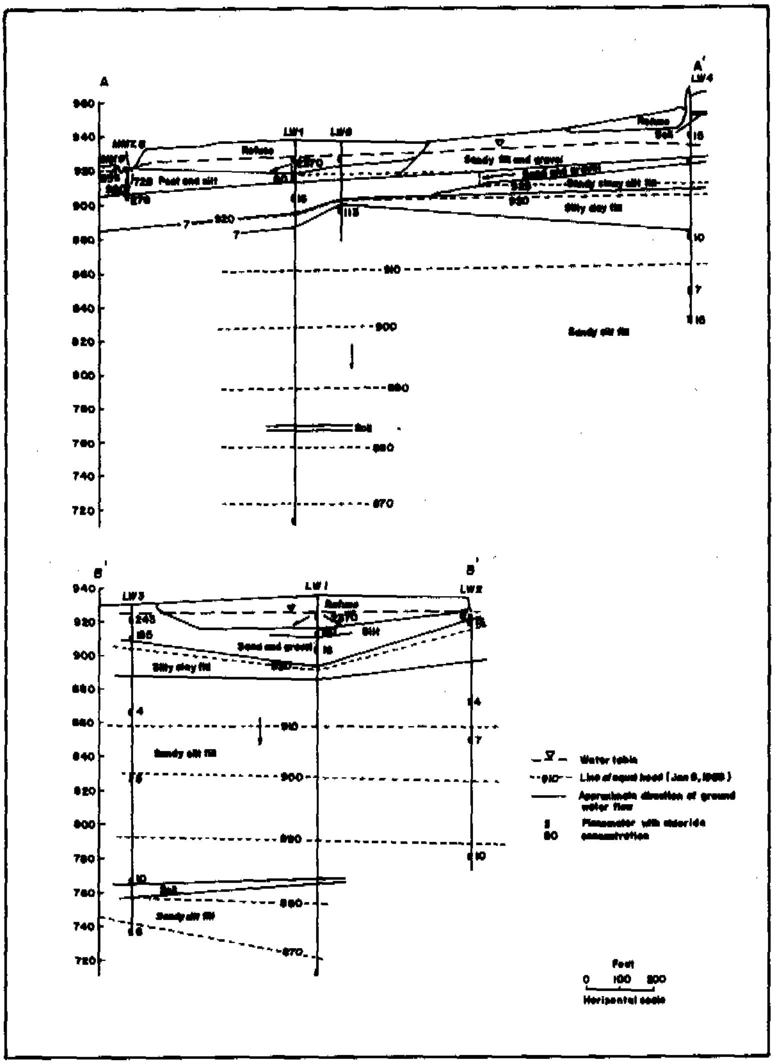


Fig. 5. Landfill cross-sections. Cross section A-A' (top) and B-B' (bottom) of the Woodstock landfill with selected chloride concentrations. A vertical gradient in the sity clay till and a strong lateral flow of ground water in the shallow materials above the till are evident. Ground water discharges into the drainage ditch near MM 7 and MM 8, cross section A-A'.

Source: "Hydrogeology of Solid Waste Disposal Sites in Northeastern Illinois", by G.M. HUGHES, R.A. LANDON and R.N. FARVOLDEN of the Illinois State Geological Survey. Published by the U.S. EPA, 1971.

Table 2. Decision Table for Landill Site Selection

Site name	Comments	Score
Land requirement	-	-
Accessibility	-	-
Drainage	-	-
Soil as interface	-	-
Soil as cover	-	-
Depth to water table	-	-
Haul distance	-	-
Hydrogeology	-	-
Climate	-	-
Topography	-	-
Cost considerations	-	-
Other factors	-	-

In general, the number and the location of boreholes should simply be whatever is adequate to support the plan. The general guidelines for the borehole requirements are given in Table 3. These are not strict, and hence may be varied as per the complexity of the site. The distribution of boreholes over the site area can only be determined in relation to the actual site.

Table 3. Borehole Requirements - General Guidelines

Site Size	Approximate Number	General Configuration
Up to 10 acres	3	
10 to 50 acres	5 - 6	
50 to 100 acres	8 - 9	
100 acres or more	11 - 15	

Source: NOBLE (1976)

In general the choice of drilling method is governed by the expected nature of the site geology, equipment availability and economics. There are 5 types of drilling techniques: core boring, auger, hollow stem auger, mud rotary and air rotary.

A summary of drilling techniques for different soil types is given in Table 4.

Table 4. Summary of Landfill Site Drilling Techniques

	Technique				
	Coring Drill	Auger	Hollow Stem Auger	Mud Rotary	Air Rotary
Sand - Dry	X		X	X	
Wet	X		X	X	
Silt	X	X	X	X	X
Clay	X	X	X	X	X
Rock Weathered	X			X	X
In situ	X			X	X

Soils : During the course of boring operating, soil samples should be taken at 5 feet intervals or at each major change in soil type — whichever occurs first. Dependent upon the depth of sampling, the soil will ultimately provide cover material for the compacted refuse or it will form the crucial interface between refuse and ground water table. The soil for interface should be analysed for:

- soil permeability
- pH
- cation exchange capacity

For soil as cover, the sieve analysis is very important.

If the site itself has been carefully chosen, the depth of ground water will be quite adequate to allow an appropriate depth of soil interface. The direction of ground water movement should be established, wherever possible.

At the site, all the relevant existing surrounding conditions should be identified. This includes topography, slopes, vegetation, streams, ponds, lakes, soil types, buildings, roads, land uses, population, public facilities, open space and recreational facilities.

A base topography map delineating existing site topography prepared to a convenient scale should be available. Contour intervals should be 1.5 metres (5 ft). The map should include the entire site and encompass surrounding areas that may be affected by site operations.

Basic information on site hydrology and geology collected for site selection should be made use of here for detailed idea. The quantity of available soil cover material should be assessed.

SITE PREPARATION

A list of site preparation needs are as follows:

- Enclosure
- Clearance and clean up
- Access road
- Employee facilities
- Equipment facilities
- Monitoring

A fence should be put up even before the site clearing begins. This is for safety and security, privacy and noise (psychological reasons only).

Safety is in the sense that it prevents children from playing and scavengers can also be easily excluded. The privacy factor really has an impact upon the extent of community acceptance of operation. There is no noise attenuation due to fencing, but psychologically, noise may be tolerated if the origin of the noise cannot be seen.

Trees and bushes that hinder landfill equipment or collection vehicles must be removed. Obviously, all this material will be the first to be buried when the operation starts. A large site should be cleared in increments to avoid erosion and scouring of the land. If possible, natural windbreaks and green belts of trees should be left in strategic areas to improve appearance and operation. Site clearance should also include setting out markers to indicate the boundaries of each fill area and the layout of the access roads.

These access roads on the site represent the major arteries which keep the operation running smoothly. They should be designed to support the anticipated volume of truck traffic. The roadway should consist of 2 lanes for 2-way traffic. Most uphill grades should not be more than 7 per cent while downhill grades less than 10 per cent.

Intermediate type bituminous roads which will stand the test of time and minimise maintenance costs are strongly recommended. If not, the gravelly soils will provide the best alternative to roads. A complete synopsis of the roadway characteristics of different soil types is given in Table 5.

A building is needed for office space and employee facilities. Sanitary facilities should be provided for both landfill and collection personnel. A building should be provided for equipment storage and maintenance. For small sites with a limited life, a minimum of portable sanitary facilities, safe drinking water and a place for eating lunch and changing clothes should be provided. Ideally 2 lockers should be provided for each employee — one for street clothes, and other for working clothes. For sites with a 10-year life and with an annual waste input of 200,000 tonnes or greater, permanent structures should be considered.

Table 5. Roadway Soil Characteristics

Major Divisions		Name	Value as Foundation When Not Subject to Frost Action	Value as Base Directly Under Wearing Surface	Potential Frost Action	Compressibility and Expansion	Drainage Characteristics	Compaction Equipment	Unit Dry Weight Lb. Per Cu. Ft.
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	Gravel of sandy gravel, well-graded	Excellent	Good	None to very slight	Almost none	Excellent	Crawler type tractor, rubber tired equipment, steel wheeled roller	125-140
		Gravel or sandy gravel, poorly-graded	Good to excellent	Poor to fair	None to very slight	Almost none	Excellent	Crawler type tractor, rubber tired equipment, steel wheeled roller	120-130
		Gravel or sandy gravel, uniformly graded	Good	Good	None to very slight	Almost none	Excellent	Crawler type tractor, rubber tired equipment	115-125
		Silty gravel or silty sandy gravel	Good to excellent	Fair to good	Slight to medium	Very slight	Fair to poor	Rubber tired equipment, sheepsfoot roller, close control of moisture	130-145
		Clayey gravel or clayey sandy gravel	Good	Poor	Slight to medium	Slight	Poor to practically impervious	Rubber tired equipment, sheepsfoot roller	120-140
	SAND AND SANDY SOILS	Sand or gravelly sand, well-graded	Good	Poor	None to very slight	Almost none	Excellent	Crawler type tractor, rubber tired equipment	110-130
		Sand or gravelly sand, poorly-graded	Fair to Good	Poor to not suitable	None to very slight	Almost none	Excellent	Crawler type tractor, rubber tired equipment	105-120
		Sand or gravelly sand, uniformly graded	Fair to good	Not suitable	None to very slight	Almost none	Excellent	Crawler type tractor, rubber tired equipment	100-115
		Silty sand or silty gravelly sand	Good	Poor	Slight to high	Very slight	Fair to poor	Rubber tired equipment, sheepsfoot roller, close control of moisture	120-135
		Clayey sand or clayey gravelly sand	Fair to Good	Not suitable	Slight to high	Slight to medium	Poor to practically impervious	Rubber tired equipment, sheepsfoot roller	105-130
	LOW COMPRESSIBILITY LL< 50	Silts, sandy silts, gravelly silts, or diatomaceous soils	Fair to poor	Not suitable	Medium to very high	Slight to medium	Fair to poor	Rubber tired equipment, sheepsfoot roller, close control of moisture	100-125
		Lean clays, sandy clays, or gravelly clays	Fair to poor	Not suitable	Medium to high	Medium	Practically impervious	Rubber tired equipment, sheepsfoot roller	100-125
		Organic silts or lean organic clays	Poor	Not suitable	Medium to high	Medium to high	Poor	Rubber tired equipment, sheepsfoot roller	90-105
	HIGH COMPRESSIBILITY LL>50	Micaceous clays or diatomaceous soils	Poor	Not suitable	Medium to very high	High	Fair to poor	Rubber tired equipment, sheepsfoot roller	80-100
		Fat clays	Poor to very poor	Not suitable	Medium	High	Practically impervious	Rubber tired equipment, sheepsfoot roller	90-110
		Fat organic clays	Poor to very poor	Not suitable	Medium	High	Practically impervious	Rubber tired equipment, sheepsfoot roller	80-105
PEAT AND OTHER FIBROUS ORGANIC SOILS		Peat, humus, and other	Not suitable	Not suitable	Slight	Very high	Fair to poor	Compaction not practical	

Souce: Adapted from U.S. Army Corps of Engineers, Engineering Manual, Part III, Chapter 2, Appendix "A".

Covered storage should be provided for all major items of landfill equipment. Floor design should, of course, reflect the weight range of the vehicle not forgetting the concentrated load on a hydraulic jack. An inventory for a small maintenance shop which would also provide tools for jobs around the site might be as shown in Table 6. In addition, a small repair shop might be equipped as shown in Table 7.

Table 6. Tools for a Small Maintenance Shop

. Complete set of small hand tools (as often provided by the manufacturer)
. Two 15 tonne screw jacks, one 20 tonne hydraulic jack
. One ½ tonne, one 1-tonne and one 2 tonne chain hoist
. An assortment of wire rope slings and shackles
. One 200 amp portable arc welder, one 300 amp stationary arc welder, or a gas combination welding and cutting outfit

Table 7. Equipment for a Small Repair Shop

. One bench vice and one large floorstand vice
. An assortment of drop lights and extension cords
. One bench-type drill press and assorted drills
. One bench-type grinder
. A good assortment of test equipment for electrical repair work

SANITARY LANDFILL DESIGN

After the selection of the site, on the basis of a review of the available preliminary information, an engineering design report for each site is prepared.

The factors that must be considered in an engineering design are as follows:

- Land requirements;
- types of wastes that must be handled;
- evaluation of seepage potential;
- design of drainage and seepage control facilities;
- development of a general operation plan;
- design of solid waste filling plan; and
- determination of equipment requirements.

The more important individual factors that must be considered are given in Table 8. Careful consideration must be given to the final use or uses to be made of the completed site.

The final density of solid wastes placed in a landfill varies with the compactability of solid wastes and mode of operation. The typical compactability data of some of the components is given in Table 9 in which volume reduction factors are given for both normally compacted and well compared landfills. Compacted density is calculated, with this, and is then used for calculating the area requirements.

The recovery of materials and energy from solid wastes will also reduce the landfill area requirements. The amount of the reduction will depend on the components to be recovered. In cases where the computed compacted density changes significantly as a result of material recovery program the required landfill area can also be reduced by the ratio of compacted density (TCHOBANDGLOUS et al., 1979). Anyhow large changes in the density value will not be observed with materials recovery.

LANDFILL OPERATION

The design of sanitary landfill will dictate the method of operation. There are basically 2 methods of operation, the trench method and the area method. Sometimes, a third method can be a modification or combination of the above methods. The 2 methods differ primarily in that confining lateral earthern walls are used in the trench method but not in the area method.

Trench Method

In this method, waste is spread and compacted in an excavated trench. Cover material, which is taken from the spoil of the excavation, is spread and compacted over the waste to form the basic cell structure, as shown in Fig. 6. The bottom of the trench should be slightly sloped for drainage and provision should be made for surface water to runoff at the low end of the trench. The trench can be as deep as soil and ground water conditions safely allow. The trench should at least be twice as wide as any compacting equipment that will work in it. This method eliminates excess soil movement, allows a clean operation and reduces the amount of soil needed for daily cover. It is suitable only for small operations.

Area Method

In this method, the waste is spread and compacted on the natural surface of the ground, and cover material is spread and compacted over it, as shown in Fig. 7. The area method is used on flat or gently sloping land and also in quarries, strip mines, ravines, valleys, or other land depressions.

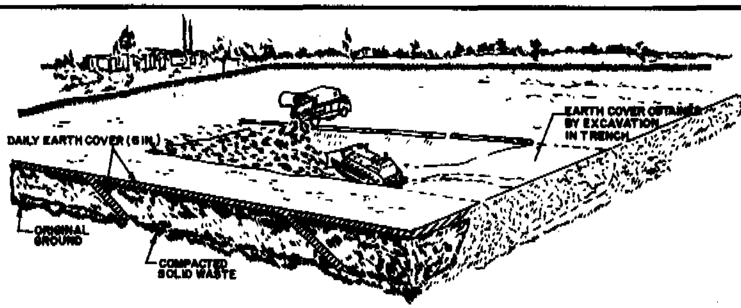
Table 8. Important Factors that must be Considered in the Design Operation of Sanitary Landfills

Factor	Remarks
Design	
Access	Paved all weather access roads to landfill site; temporary roads to unloading areas.
Cell design and construction	Will vary depending on whether gas is to be recovered; each day's wastes should form one cell; maximum depth of 10 ft; cover at end of day with 6 in of earth; gravel gas vent should be installed every 60 to 200 ft.
Cover material	Maximise use of onsite earth materials; approximately 1 yd^3 of cover material will be required for every 4 to 6 yd^3 of solid wastes; mix with sealants to control surface infiltration.
Drainage	Install drainage ditches to divert surface water runoff; maintain 1 to 2 per cent grade on finished fill to prevent ponding.
Equipment requirements	Vary with size of landfill.
Fire prevention	Water onsite; if nonpotable, outlets must be marked clearly; proper cell separation prevents continuous burn through if combustion occurs.
Groundwater protection	Divert any underground springs; if required, install sealants for leachate control; install wells for gas and ground water monitoring.
Land area	Area should be large enough to hold all community wastes for a minimum of 1 yr but preferably 5 to 10 yr.
Landfilling method	Selection of method will vary with terrain and available cover.
Litter control	Use movable fences at unloading areas; crews should pick up litter at least once per month or as required.
Operation plan	With or without the codisposal of treatment plant sludges and the recovery of gas.
Spread and compaction	Spread and compact waste in layers less than 2 ft. thick.
Unloading area	Keep small, generally under 100 ft. on a side; operate separate unloading areas for automobiles and commercial trucks.
Operation	
Communications	Telephone for emergencies.
Days and hours of operation	Usual practice is 5 to 6 days/wk and 8 to 10 h/day.
Employee facilities	Restrooms and drinking water should be provided.
Equipment maintenance	A covered shed should be provided for field maintenance of equipment.
Operational records	Tonnage, transactions, and billing if a disposal fee is charged.
Salvage	No scavenging; salvage should occur away from the unloading area; no salvage storage onsite.
Scales	Essential for record keeping if collection trucks deliver wastes capacity to 100,000 lb.

Table 9. Typical Compaction Factors for Various Solid Waste Components as Discarded

Component	Compaction factors for component in landfills		
	Range	Normal compaction	Well compaction
Food wastes	0.2-0.5	0.35	0.33
Paper	0.1-0.4	0.2	0.15
Cardboard	0.1-0.4	0.25	0.18
Plastics	0.1-0.2	0.15	0.10
Textiles	0.1-0.4	0.18	0.15
Rubber	0.2-0.4	0.3	0.3
Leather	0.2-0.4	0.3	0.3
Garden trimmings	0.1-0.5	0.25	0.2
Wood	0.2-0.4	0.3	0.3
Glass	0.3-0.9	0.6	0.4
Tin cans	0.1-0.3	0.18	0.15
Nonferrous metals	0.1-0.3	0.18	0.15
Ferrous metals	0.2-0.6	0.35	0.3
Dirt, ashes, brick, etc.	0.6-1.0	0.85	0.75

Source: TCHOBANDGLOUS, G. et al, (1979)



In the trench method of sanitary landfilling, the collection truck deposits its load into a trench where a bulldozer spreads and compacts it. At the end of the day, the trench is extended, and the excavated soil is used as daily cover material.

Source: Sanitary Landfill Design and Operation, EPA, 1972

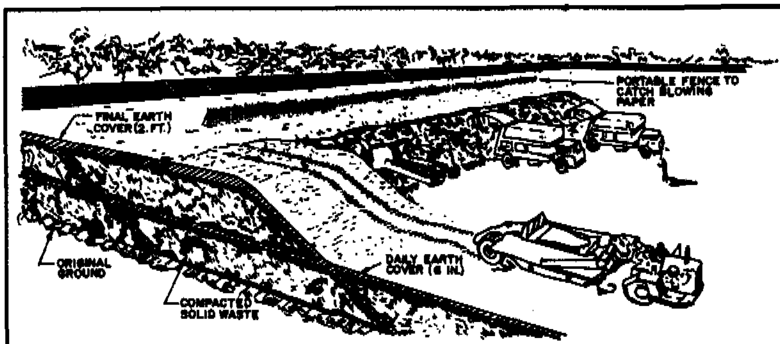
Fig. 6. Trench Method.

The primary considerations in an area method are:

- The truck unloading position;
- the distance of borrow area for cover;
- the method of transporting the cover material;
- the path over which the cover material must be transported, and;
- the confinement of the refuse both vertically and horizontally

Criteria for Manual or Mechanised Methods

The above 2 methods of operation can be achieved either by manual or mechanised operation. The primary criteria for the selection of the method are the density of wastes and compaction. The typical characteristics of wastes of industrialised countries and developing countries is as follows (FLINTOFF, 4).



In the area method, a bulldozer spreads and compacts the waste on the ground, and a scraper is used to haul the cover material at the end of the day's operations.

Source: Sanitary Landfill Design and Operation, EPA, 1972

Fig. 7. Area Method.

Industrial Country

(Data from "Controlled Tipping", BEVAN, Institute of S.W. management, London).

Density as tipped from vehicle before compression	270 kg/m.^{3}
Density after 3 days	628 " "
Density after 1 year	760 " "

Developing Country

(From "Garbage disposal for Calcutta City" NEERI, India).

Density of refuse arriving at disposal site	518-573 kg/m.^{3}
Density of dumped refuse (6 months old)	1,128 kg/m.^{3}

From the figures quoted above it would appear that high density wastes, which are typical of developing countries, do not require initial compaction. It can be concluded, that in developing countries the employment of a mechanical plant to achieve initial compaction is not necessary.

Manual operation could be fairly effective if proper care is taken in the selection of the site and in the formation of strips.

An all-weather access road must be provided first. The road can be built from construction waste. The position of the first strip to be raised should be defined by 2 rows of pegs driven into the ground, and the final level of the first layer should be indicated by occasional posts.

A three-time "drag" or rake, with a handle up to 2 metres in length is the most effective tool for embankments. The vehicle delivering the wastes should be reversed to a point a close as possible to minimise the movement of waste by hand. To reduce the risk of a vehicle reversing too far, wooden obstructions should be placed, at the point of rear wheel. To avoid the rear wheels of the vehicle sinking into the newly deposited wastes, a small area should be covered with steel plates, as in Fig. 8.

Very little lateral movement of wastes is needed if they are well placed. However, the labourers need to stand in the wastes, and hence protective clothing should be provided. From time to time, covering material should be delivered to the site. The volume of cover material ranges from one seventh to one fifth of the volume of wastes. The density of wastes at this stage will be at least 50 per cent higher. The covering material should be spread to a thickness of at least 15 cm, and preferably up to 25 cms. The best tools for this work are shovels and wide garden rakes with short tines.

Prolonged heavy rain is the only real obstacle. Under such circumstances, it is advisable to provide a portable roadway across the strip in the form of old railway sleepers. It is necessary to be prepared to recover vehicles where one or more wheels have sunk up to the axles. For this, heavy jacks and timbers are necessary.

Table 10. Labour and Covering Material Scale of Requirement

Population	Tonnes/day @500 gms/ person/day	m^3/day @330 kg/m^3	In-place volume m^3	Covering material, m^3/day	Men
20,000	10	30	20	4	2
50,000	25	75	50	10	3
100,000	50	150	100	20	6

The probable scale of requirement of labour and covering material at typical rate of generation and density are given in Table 10. Manual operations are good only for small scales of operation.

SITE MONITORING

Site monitoring of any type involves some expense. Hence it is important to select sites for landfills that will need only minimal monitoring. The cost and extent of monitoring primarily depends on the nature of the solid waste and hydrogeology of the site. The bigger the size of operation, the higher the cost. The items to be monitored are:

1. Characteristics of leachate generation within the site;
2. Ground water and surface water quality in the immediate vicinity of the site and at same reasonable distance around the site;
3. Characteristics of gases generated in the refuse mass and the progression of the gases from the landfill site;
4. Erosion of the cover soil from the site;
5. General characteristics and approximate quantities of hazardous and toxic wastes deposited in the site; and
6. The quantity and characteristics of any leachate that is collected at the site and directed to another location such as sewer.

Of the items noted, leachate monitoring and gas movement are generally of prime importance. Hence they are discussed in detail here.

Leachate Monitoring

Ground water or infiltrating surface water moving through solid waste can produce leachate. Leachate may be defined as liquid that has percolated through solid waste and has extracted dissolved or suspended materials from it (SALVATO et al, 1971). Representative data on the

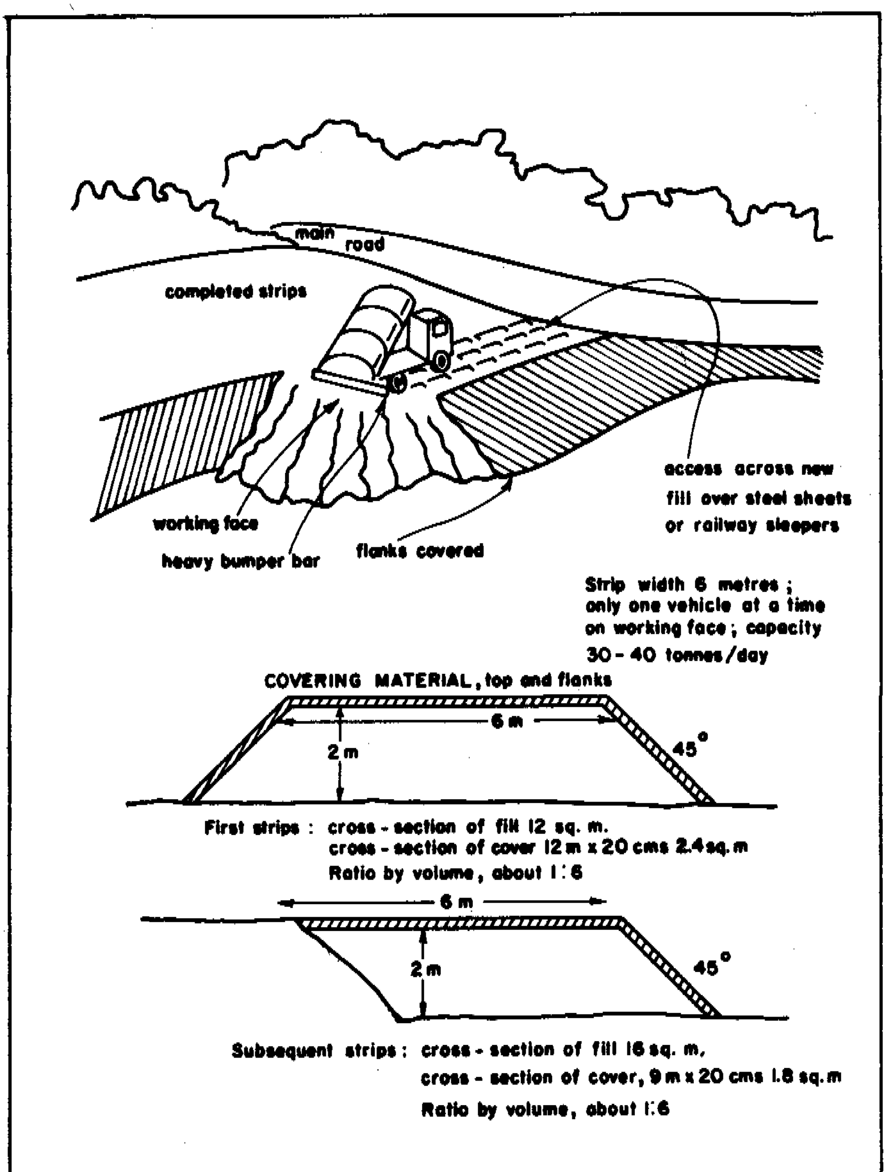


Fig. 8. Small Manually-Operated Sanitary Landfill

chemical characteristics of leachate are given in Table 11, (with range values and typical values). In general, it has been found that the quantity of leachate is a direct function of external water entering the landfill. A simple water budget for a sanitary landfill may be represented as in Fig. 9 (NOBLE, 1976).

The rate of seepage of leachate from the bottom of a landfill can be estimated by Darcy's law, which can be expressed as:

$$Q = -KA \frac{dh}{dL}$$

where Q = leachate discharge per unit time.
K = coefficient of permeability
A = cross-sectional area through which the leachate flows
dh/dL = the hydraulic gradient.

The minus sign arises from the fact that the head loss "dh" is always negative. The coefficient of permeability is also known as the hydraulic conductivity, the effective permeability, or the seepage coefficient.

The coefficient of permeability is expressed in gallons per day per $foot^2$ or feet per day (in FPS units). The conversion between these factors is accomplished by noting that 7.84 $gal/day/ft^2$ = 1 ft/day. Typical values for the coefficient of permeability for various soils are given in Table 12 (SALVATO et al).

The physical conditions of the problem are shown in Fig. 10. The landfill cell has been placed in a surface aquifer, composed of material of moderate permeability, which overlies a bedrock aquifer. In this case. it is possible to have two different piezometric water levels if wells are placed in the surface and bedrock aquifers.

The 2 main problems of interest with regards to the movement of leachate here are:

1. The rate at which the leachate seeps from the bottom of the landfill into the ground water in the surface aquifer.

2. The rate at which ground water from the surface aquifer moves into bedrock aquifer.

Table 11. Data on the Composition of Leachate from Landfills

Constituent	Value † mg/l	
	Range ‡	Typical
BOD_5 (5-day biochemical oxygen demand)	2,000 - 30,000	10,000
TOC (total organic carbon)	1,500 - 20,000	6,000
COD (chemical oxygen demand)	3,000 - 45,000	18,000
Total suspended solids	200 - 1,000	500
Organic nitrogen	10 - 600	200
Ammonia nitrogen	10 - 800	200
Nitrate	5 - 40	25
Total phosphorus	1 - 70	30
Ortho phosphorus	1 - 50	20
Alkalinity as $CaCO_3$	1,000 - 10,000	3,000
pH	5.3 - 8.5	6
Total hardness as $CaCO_3$	300 - 10,000	3,500
Calcium	200 - 3,000	1,000
Magnesium	50 - 1,500	250
Potassium	200 - 2,000	300
Sodium	200 - 2,000	500
Chloride	100 - 3,000	500
Sulphate	100 - 1,500	300
Total iron	50 - 600	60

† Except pH.
‡ Representative range of value. Higher maximum values have been reported in the literature for some of the constituents.

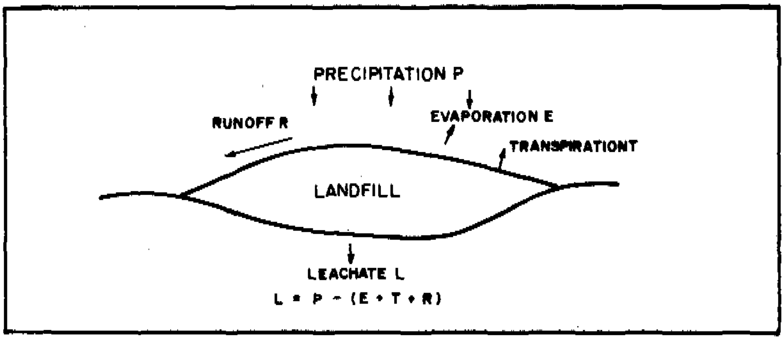


Fig. 9. Water Budget for a Sanitary Landfill

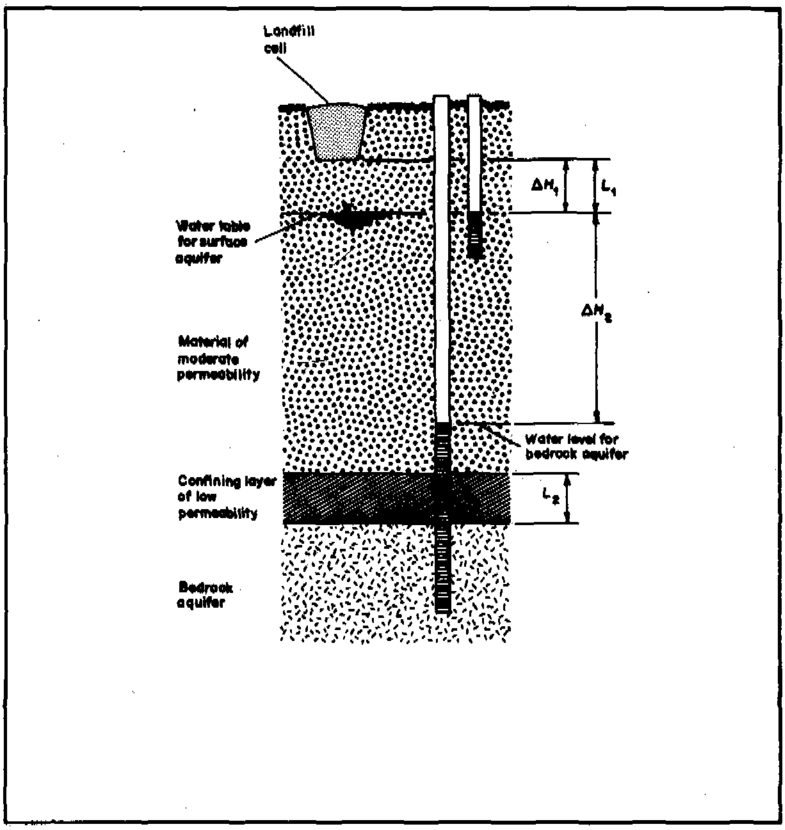


Fig. 10. Definition Sketch for Determination of Seepage from Landfills and from Surface to Subsurface Aquifers.

Table 12. Typical Permeability Coefficients for Various Soils (Laminar Flow)

Material	Coefficient of permeability, K_s	
	ft/day	gal/day/ft^2
Uniform coarse sand	1,333	9,970
Uniform medium sand	333	2,490
Clean, well-graded sand and gravel	333	2,490
Uniform fine sand	13.3	100
Well-graded silty sand and gravel	1.3	9.7
Silty sand	0.3	2.2
Uniform silt	0.16	1.2
Sandy clay	0.016	0.12
Silty clay	0.003	0.022
Clay (30 to 50 per cent clay sizes	0.0003	0.0022
Colloidal clay	0.000003	0.000022

Note: ft/day x 0.3048 = m/day
gal/day/ft^2 x 0.0408 = m^3/day/m^2

Problem 1

The leachate flow rate from the landfill to the upper ground water is computed by assuming that the material below the landfill to the top of the water table is saturated and that a small layer of leachate exists at the bottom of the fill. Under these conditions:

$$Q \text{ (gal/day} = K \text{ (gal/day/ft}^2\text{) (ft}^2\text{)}$$

(assuming that flow occurs through 1 ft^2).

Problem 2

The rate of movement of water from the upper aquifer to the lower aquifer is given by:

$$Q \text{ (gal/day)} = K \text{ (gal/day/ft}^2 \; A \text{ (ft}^2\text{)} \; \frac{h_2\text{(ft)}}{L_2\text{(ft)}}$$

In this problem, the thickness of the confirming layer is used to determine the hydraulic gradient.

Leachate Movement Control

The best practice of leachate control calls for its elimination or containment, rather than taking risks in allowing leachate to percolate to the ground water. To date (1978) the use of clay has been the favoured method of reducing or eliminating the percolation of leachate. Membrane liners have also been used, but are expensive and require extra care during filling operations.

Elimination of surface water infiltration also controls the movement of leachate (Fig. 9). This is the major contributor to the total volume of leachate. With the use of an impermeable clay layer and an appropriate surface slope (1 to 2 per cent), and adequate drainage, surface infiltration can be controlled effectively.

Gas Monitoring

The gases generated from a landfill should be either vented to the atmosphere or collected for energy. Gases found in landfills with their molecular weights and densities are given in Table 13. Carbon dioxide and methane are the principal gases produced from the anaerobic decomposition.

Table 13. Molecular Weight and Density of Gases Found in Sanitary Landfills at Standard Conditions ($0^{o}C$, 1 atm)

Gas	Formula	Molecular weight	Density	
			g/l	lb/ft^3
Air	-	-	1.2928	0.0808
Ammonia	NH_3	17.03	0.7708	0.0482
Carbon dioxide	CO_2	44.00	1.9768	0.1235
Carbon monoxide	CO	28.00	1.2501	0.0781
Hydrogen	H_2	2.016	0.0898	0.0056
Hydrogen sulphide	H_2S	34.08	1.5392	0.0961
Methane	CH_4	16.03	0.7167	0.0448
Nitrogen	N_2	28.02	1.2507	0.0782
Oxygen	O_2	32.00	1.4289	0.0892

Although most of the methane escapes to the atmosphere, both methane and carbon dioxide have been found in concentrations up to 40 per cent at lateral distances of up to 400 ft from the edges of the landfill (TCHOGANDGLOUS et al, 1979) for unvented landfills, the extent of this lateral movement varies with the characteristics of the cover material and the surrounding soil. With proper venting, methane will not be a problem. But carbon dioxide, being 1.5 times denser than air and 2.8 times as dense as methane, tends to move towards the bottom (Table 13). Ultimately it reaches the ground water, and lowers the pH because it is easily soluble in water. This in turn increases the hardness and mineral content through stabilisation.

The solubility of the gases in water is given in Table 14. The corresponding concentration of a gas in solution can be computed using Henry's Law:

$$C_s = K_s P$$

where

C_s = saturation concentration as the gas in water ml/l

K_s = coefficient of absorption, ml/l

P = partial pressure of the gas in the gas phase, expressed as a fraction.

Gas Movement Control

Permeable Method: Gas vents are constructed as shown in Fig. 11. The spacing of cell vents (Fig. 11-a) depends on the width of the cells, but usually varies from 60 to 200 ft. Barrier vents (Fig. 11-b) or well vents (Fig. 11-c) can also be used to control the lateral movement of gases.

Downward movement of gases can be controlled by installing perforated pipes in the gravel layer at the bottom of the landfill.

Impermeable Methods

The movement of landfill gases through adjacent soil formations can be controlled by constructing barriers that are more impermeable than the soil. Some of the landfill sealants for this use are given in Table 15. Of these the use of compact clay is most common. The thickness varies from 6 to 48 inches depending upon the type of clay and degree of control required. Landfill gas can be recovered in this case.

Table 14. Data on the Absorption Coefficients for the Gases Found in Sanitary Landfills.*

(Millilitres of gas reduced to 0°C and 760 mm Hg per litre of water when the partial pressure of the gas is 760 mm Hg)

Gas	Formula	Molecular weight	Temperature, °C		
			0	10	20
Air	-	-	29.18	22.84	18.68
Carbon dioxide	CO_2	44.00	1713	1194	878
Carbon monoxide	CO	28.00	35.4	28.2	23.2
Hydrogen	H_2	2.016	21.5	19.6	18.2
Hydrogen sulphide	H_2S	34.08	4670	3399	2582
Methane	CH_4	16.03	55.6	41.8	33.1
Nitrogen	N_2	28.02	23.5	18.6	15.5
Oxygen	O_2	32.00	48.9	38.0	31.0
Vapour pressure of water, mm Hg	-	-	4.58	9.21	17.5

* Adapted from (SALVATU et al, 1971)

Other Possible Monitoring

With regards to the monitoring of settlement at a landfill site, there is no acceptable technique. Settlement plates, usually concrete or steel squares with sides 2 ft have been successful. Reinforcing bars 0.6 m - 1.2 m can also be implanted vertically into the cover soil and refuse (A.S.C.E., 1976).

If completed landfills are used for agricultural purposes, then erosion is of concern. Erosion rates of 6.3 mm - 13 mm (0.25 in - 0.5 in) per year have been suggested as acceptable limits (A.S.C.E., 1976).

It would be a good practice to monitor the types of material being brought to the site. If problems do develop in the future, then the location of that specific wastes can be established.

In monitoring the rate of organic matter stabilisation, consideration must be given to measuring the temperature of the decomposing refuse mass. Temperature data, together with data on gas generation, leachate production and settlement provide fairly complete monitoring of degradation.

Table 15. Landfill Sealants for the Control of Gas and Leachate Movement

Sealant		Remarks
Classification	Representative types	
Compacted soil		Should contain some clay or the silt
Compacted clay	Bentonites, illites, kaolinites	Most commonly used sealant for landfills; layer thickness varies from 6 to 48 in; layer must be continuous and not allowed to dry out and crack.
Inorganic chemicals	Sodium carbonate, silicate, or pyrophosphate	Use depends on local soil characteristics.
Synthetic chemicals	Polymers, rubber latex	Experimental, use not well established.
Synthetic membrane liners	Polyvinyl chloride, butyl rubber, hypalon, polyethylene, nylon-reinforced liners	Expensive, maybe justified where gas is to be recovered.
Asphalt	Modified asphalt, rubber-impregnated asphalt, asphalt-covered polypropylene fabric, asphalt concrete	Layer must be thick enough to maintain continuity under differential settling conditions.
Others	Gunite concrete, soil cement, plastic soil cement	

Sites are designed to accept a specific amount of wastes. And hence periodic monitoring of in-place density at the site will provide a valuable operating tool. Weight data from scales of other means, in addition to field survey information are necessary to make this calculation.

SITE MANAGEMENT

Management of a sanitary landfill site involves a wide range of responsibilities. The responsibility for operating a sanitary landfill is normally determined by the community administrative structure involved, and it should be suited to its conditions. Continuity of management over the life of the site is desirable and a site should be managed in an engineering sense.

There are basically 2 financial decisions to be made in the management of a sanitary landfill. How to finance the capital requirements and how to meet the operating costs. Operating costs include salaries, utilities, fuel and equipment maintenance. There are several sources of funds to meet the capital and operating costs. Some of them are taxes,

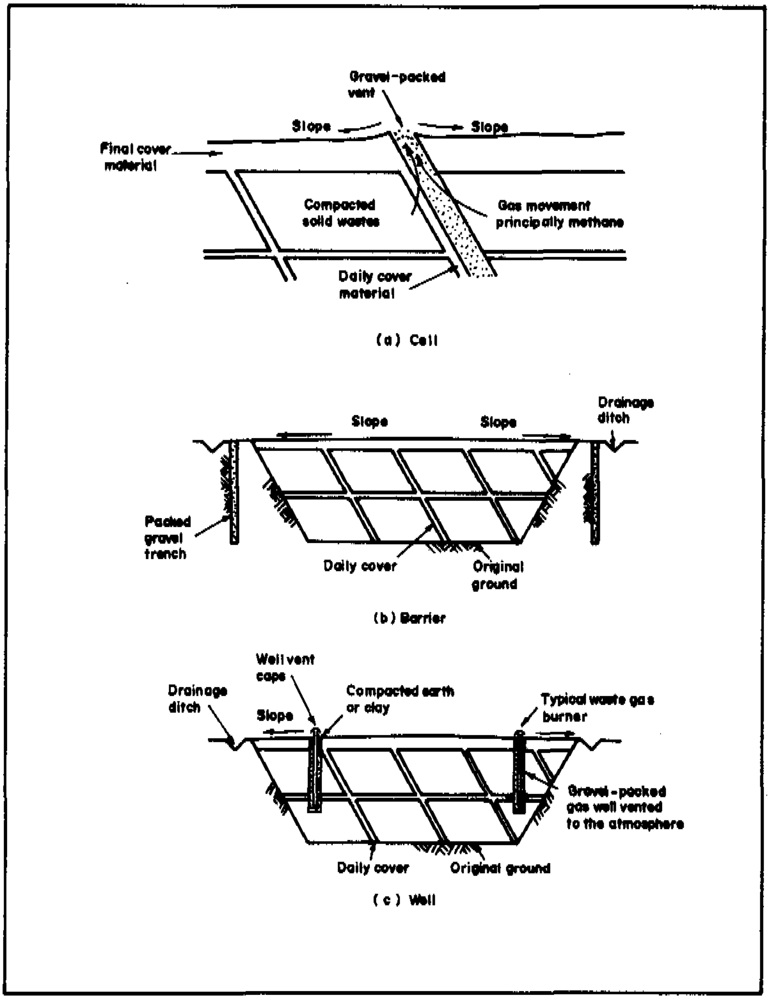


Fig. 11. Types of Vents used to Control the Lateral Movement of Gases in Sanitary Landfills

grants or subsidies and bonds. Loans are available from private companies and local governments. The United States Environmental Protection Agency's office of Solid Waste Management programmes has prepared a publication, which has several good forms that can be used in cost accounting (ZAUSNER, 1969). The important operation costs include: wages and salaries, maintenance of equipment and fuel, utilities, depreciation and interest on buildings and equipment, and overheads.

General Administration

Site Performance Evaluation: In most cases, there is a control agency that determines if the operation is being conducted in a manner that safeguards against environmental pollution. An evaluation checklist for the operation of land disposal sites was developed by U.S.E.P.A. as given in Table 16. The administrative section of the organisation operating the landfill should evaluate the operation periodically.

Personnel: To secure and retain competent employees, the administration must have a systematic personnel management plan. A list of positions for a landfill operation will include and administrative tasks and operating tasks. Then the management must determine how many employees are needed. As the size of the operation increases, a division of labour will become necessary for sustained efficiency. Wages must be comparable with similar employment elsewhere. It is desirable to have on the job training, insurance plans, pension plans, uniforms, paid holidays and sick leave programmes.

Supervision at Site: At least 2 persons should always be present during landfill operations. This is a safety measure. At a large site, a superintendent or a project engineer may be required. A multi-shift operation, would require supervisors for each of the shift.

Public Relations: A key aspect of public relations is the procedure for handling citizens' complaints. Deficiencies in operating methods or employee courtesy should be investigated and acted on promptly. Local political support should be sought to reinforce the landfill concept and its benefits. Periodic news releases regarding how the landfill is progressing towards its final design should be issued. Convincing the public of the advantages of a sanitary landfill is a tedious process, but can be achieved by explanation and education.

For security's sake, the landfill sites should be surrounded either by a natural barrier or a fence. The purpose is to avoid accidents, and to discourage people other than employees, legitimate users and visitors from entering.

Equipment Maintenance: The supervisor should outline a comprehensive preventive maintenance programme. In some large landfill operations, there is often a need to charge one individual with the daily responsibility of equipment maintenance. Landfill managers should make sure

Table 16. Evaluation Checklist for Operation of Land disposal Sites

CATEGORY	NO.	OPERATIONS PROCEDURE TO BE EVALUATED	YES	NO
Site Accesibility	1	Site accessible to vehicles by all-weather roads leading from public road system		
Water	2	Surface water courses and run off diverted from site		
Quality	3	Leachate collection and treatment systems provided where necessary		
Air	4	Opening burning prohibited		
Quality	5	Decomposition gas migration vented to atmosphere		
	6	Any concentration of decomposition gases in a manner that will pose an explosion or toxicity hazard.		
Vectors	7	Disposal site operator prepared to implement contingency programmes for vector control when necessary.		
Esthetics	8	Litter blowing controlled (portable fences, etc.)		
	9	Litter removed from fences at end of each operating day		
Cover	10	Daily cover applied		
Material	11	Compacted daily cover thickness at least 6 inches		
	12	Intermediate cover applied where necessary		
	13	Compacted intermediate cover thickness at least 12 inches		
	14	Final cover applied		
	15	Compacted final cover at least 24 inches		
Compaction	16	Landfill equipment capable of functioning on a slope not flatter than one (vertical) to three (horizontal)		
	17	Solid wastes spread in layers not more than 2 feet thick		
	18	Solid wastes compacted to smallest practical volume		
	19	Preventive maintenance program established for landfill equipment.		
	20	Operating manual developed and available to employees		
Safety	21	Safety manual available for use by employees		
	22	Employees instructed about safety procedures		
	23	Employees follow safety procedures		
	24	Safety devices (e.g. roll over protective structures, slot-belts, audible reverse warning devices, fire extinguishers) provided on landfill equipment		
	25	Provision established for extinguishing fires in wastes being delivered to site, at working face, and at personnel facilities		
	26	Emergency communications equipment available		
	27	Scavenging prohibited		
	28	Access to site controlled		
	29	Access to site established by roadways only		
	30	Containers located for after-hours deposit		
	31	Traffic pattern and signs established		
Records	32	Records kept for major operational problems and complaints		
	33	Qualitative and quantitative evaluations of leachate control kept		
	34	Qualitative & quantitative evaluations of gas control kept		
	35	Qualitative & quantitative evaluations of water quality analyses kept		
	36	Vector control records kept		
	37	Dust and litter control records kept		
	38	Quantitative measurements of solid wastes received		
	39	Description of solid waste materials received		
	40	Source of solid waste materials identified		
	41	Upon completion, a detailed description of site recorded with the area's land recording authority		
Wastes	42	Bulky wastes pushed onto working face near bottom of cell		
Handling	43	State procedures for disposing of dead animals observed		
	44	Incinerator and air pollution control residues spread into working face & covered at intervals to prevent from blowing		
	45	List of excluded wastes developed and available to regular users of site		

that the operation manual for each piece of equipment is kept in a handy place, to facilitate the operators to review the manuals, when necessary. To prevent damage to the equipment, as well as to prevent accidents, only competent and qualified personnel should be allowed to operate the equipment. Equipment sizes, numbers and types must be selected to suit to the conditions. Table 17 provides a guide to the types of equipment being used at sanitary landfills and their capability to perform the required task.

Table 17. Equipment Capabilities

Type	Solid Waste		Soil Cover			Site preparing and maintaining
	Spreading	Compacting	Excavating	Covering	Hauling	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crawler dozer	E	G	E	G	NA	G
Crawler loader	G	G	E	E	F	G
Landfill compactor	G	E	P	F	NA	P
Rubber tyred dozer	G	G	F	G	NA	F
Rubber tyred loader	F	G	F	G	G	F
Scraper	NA	NA	G	G	E	F
Dragline	NA	NA	E	F	NA	F
Grader	NA	NA	G	NA	NA	G

Note: E = Excellent; G = good, F = fair; P = poor; NA = not applicable.

PROBLEMS RELATING TO LANDFILLING PRACTICES IN ASIA

The utilisation of solid wastes as materials for landfill is a widely employed method of refuse disposal in the developing countries of Southeast Asia. The presence of a large proportion of putrescible and high organic matter in their wastes is favourable from the standpoint of effective treatment and destruction of pathogenic organisms due to a rapid rise in temperature during the degradation process. Despite these advantages, however, this method poses some risks on the workers involved in deep excavation projects on a landfill site due to evolution of methane gas and other gaseous products that may result from accompanying organic decomposition (FLINTOFF). Concomitant to the successful application of landfilling to solid waste management in Southeast Asian nations are some problems which require close co-operation among the various fields of disciplines and the public. Some of the more common problems normally encountered in developing nations are presented briefly in the following discussion.

Health Problems

A higher incidence of certain diseases usually involving the skin was reported by NEERI (National Environmental Engineering Research Institute) (FLINTOFF, 1975) to occur among workers involved with town wastes. This can be attributed to the fact that the methods of sanitary landfill management adapted are loosely applied and most often result in undue exposure of the worker's skin to wastes containing faecal matter and other offensive materials. It has been observed that the risk to workers by skin contact with wastes is greater in developing countries than the industrialised nations which because of their superior economy, can readily make provisions for protective clothing such as rubber boots, gloves and overalls that can be changed and washed regularly.

Land Availability for Waste Disposal

Although most countries land availability cannot be considered a major problem at the moment, it is actually a potential cause of trouble in the light of the rapid pace of industrialisation in some areas of the region. Hong Kong and Singapore, for example, are starting to experience this as more and more wastes are being generated. In some other areas, difficulty in finding and acquiring landfill sites is influenced not by physical lack of suitable land but rather by economics and administrative processes.

Water Pollution

Water pollution in Southeast Asia is ordinarily caused by contact of deposited wastes with ground water, surface water, leachate from dumps, static water in dump sites, and the use of streams and canals for solid waste disposal by residents not provided with proper services. Surface water drainage is frequently impaired by the blockage of ditches, gullies and sometimes major waterways. In one of the British experiments (1961) concerning the generation of leachate from rainfall, it has been observed that a leachate equivalent of 220 mm was produced from an annual rainfall of 635 mm. This just indicated that pollution of surface water can be considerably reduced by minimising leachate inflows. This approach is achieved by the installation of an impervious membrane liner on the prepared floors and the laying of network of subsoil drains to intercept and collect the leachate into chamber where it is biologically filtered before being discharged into sewers (WONG)

High Moisture Content

Wastes with high mositure content are in the form of either liquids or sludges. In general, any waste containing moisture greater than 80 per cent will create problems unless special care is taken in disposal. Whenever possible, the excess moisture should be taken up by the addition of a suitable absorbent before sludges are incorporated into a landfill. If this precautionary measure is neglected, the production of more leachates is enhanced and pollution of surface water can be expected.

Bulky Wastes

Most often, bulky items present a multiplicity of problems such as vermin harbourage, unsightliness, physical hazards to operators, lures to scavengers and a danger to children. To reduce the magnitude of these problems, some preliminary treatment of the solid wastes can be employed such as crushing and pulverisation. Since cars, appliances, and big drums are partially crushable, crushing can achieve a smaller volume of landfill and therefore more space is conserved and becomes available for additional solid waste disposal. Construction and demolition debris, particularly brick, concrete, asphalt and plaster, should be laid down as a landfill base whenever possible. Most bulky items degrade very slowly and sometimes do not degrade at all (particularly plastic), hence appropriate steps should be taken to surround such objects with solid wastes of similar character such as demolition debris.

Hazardous Wastes

With the increasing complexity of industrial development, landfills are under pressure to receive many materials which they are not strictly capable of handling. Items such as liquids and sludges, gases, radioactive materials and pathological wastes should be kept away as much as possible from all sanitary landfills. Liquids and sludges contribute to the total moisture in the landfill which in effect contributes to the greater production of leachate. Gases, whether in normal or pressurised containers, should never be disposed of in the landfill, especially when the field capacity has been reached. Special provisions have to be made in disposing of radioactive wastes in order that no permeation or mixing with the landfills such as leakage or seepage can take place. Pathological wastes from hospitals, research establishments and drug manufacturers have to be disposed of in an appropriate pathological incinerator (FRANK et al).

Fire Hazards

Fires at a sanitary landfill can arise from a number of causes. Although the high density and highly putrescible wastes of developing countries are unlikely to give rise to the risks of very serious underground fires, it is always necessary as a safety precaution that special measures are taken to prevent any fire breaking out on the site. Provisions, such as a sufficient supply of water near the landfill site and adequate equipment and manpower to dig out the burning material so that water can be applied effectively, have to be made. In this way, the waste incorporated in the landfills of tropical and developing countries which has been often seen on fire can be spared from unnecessary burning.

Vectors

To prevent breeding of flies and rodents, landfills have to be covered properly. In some cases when breeding cannot be stopped by merely covering the landfill areas, insecticides have sometimes been used.

Lack of Co-operation from the Public

The lack of public co-operation is perhaps one of the most common problems in the field of solid waste management not only in developing countries of Asia but also in industrialised nations of Europe and North America. Unaware of the ultimate environmental impact of solid wastes, people tend to get rid of recoverable refuse by throwing it away anywhere they wish without thinking of reusing or recycling them. In doing so, they scatter the wastes all around making it more difficult for the cleaners to collect them. The offshoot is a series of complaints from both the public and cleansing authorities. The public express their dissatisfaction over the cleansing standards. On the other hand, the cleansing officials put the blame on the public for being unco-operative. The ultimate result is a management system with inferior cleansing standards.

Cost Factor

The cost of sanitary landfilling in Southeast Asia varies widely. This is because a number of complex factors such as land acquisition, site clearance, and preparation, operation, availability of covering material and landscaping can individually exert a significant change in the total cost involved in this method of solid waste disposal. Owing to the difficulty of land acquisition and subsequent clearing due to reasons previously mentioned these steps are becoming more expensive. Site preparation and operational costs are increasing substantially for remote sites where land acquisition is relatively easy. The experience in Hong Kong involving operational cost has shown that in general, the larger the capacity of the site, the lower the unit cost will be (WONG). A further increase in the total cost of landfilling is brought about by the increasing cost of covering material, especially when additional land and landscaping costs are necessary

Dead Animals

The disposal of dead animals sometimes becomes a problem due to health risks and bad odours that can develop. Dead animals have to be disposed of at rendering plants if possible, otherwise they can be deposited near the toe of the landfill and then covered with other refuse. The problem is further aggravated by the fact that if they are large a specially dug trench or pit has to be made for them to be buried.

Open Dumping

Open dumping normally generates various unhealthy consequences. Waste matters left mounting with time create an eyesore to onlookers despite the fact that they are reasonably far from urban centres. In Metro Manila (Philippines) however, where rapid expansion of urban land has taken place, a seemingly far away site becomes inadequate as the newly-developed sprawling areas reach the environs of the dump site in a very short time. The aftermath is a problem requiring the immediate transfer of the dumping site.

Increasing Volume of Solid Waste

As a higher standard of living is gradually attained in developing nations, more and more wastes are being generated which eventually increase the volume of wastes to be landfilled. This requires an increase in the administrative machinery, the requirement of new equipment and the maintenance of existing equipment. These are some of the immediate needs that must be satisfied to get rid of the problems of the increasing volume of solid wastes. In reality, the ultimate problem is basically a shortage of available funds.

ACKNOWLEDGEMENTS

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REFERENCES

A.S.C.E., (1976) Solid Waste Management Committee of the Environmental Engineering Division, Sanitary Landfill, ASCE-Manuals and Reports on Engineering Practice-No. 39.

Brunner, D.R., and Keller, D.J., (1971) Sanitary Landfill Design and Operation, U.S.E.P.A.

Flintoff, F., (1975) Solid Waste Management Practices in Southeast Asia, Solid Waste Management in Southeast Asia, WHO, Regional Office for S.E. Asia.

Flintoff, F., Management of Solid Wastes in Developing Countries, W.H.O. Regional Publications, Southeast Asia, Series No. 1.

Frank, K., Cross and George Noble, Hospital Solid Waste Management.

George Noble, P.E., (1976) Sanitary Landfill Design Hand Book.

Handling Guide for Potentially Hazardous Materials, Management and Safety Inc. Niles, Illinois.

Jose, H. Espiritu, Solid Waste Management Report: Metropolitan Manila Experience, Selected Paper for the Conference.

Salvato, J.A., Wilkie, W.G. and Mead, B.E., (1971) Sanitary Landfill Leaching Prevention and Control, Journal Water Pollution Control Federation, Vol. 43, no. 10.

Sorg, T.J. and Hickman, H.L., (1970) Sanitary Landfill Facts, 2nd ed. U.S. Public Health Service Publication 1792, Washington, D.C.

Tchobandglous, G., Hilary Theisen and Rolf Eliassen, (1979), Solid Wastes: Engineering Principles and Management Issues, McGraw Hill Book Company.

Weiss, S., (1974) Sanitary Landfill Technology, Noyes Data Corporation, London, England.

Wong, M.K., A Report on Controlled Tipping in Hong Kong, Selected Paper for the Conf.

Zausner, E.R., (1969) An Accounting System for Sanitary Landfill Operations, SW-15ts, Bureau of Solid Waste Management, United States Public Health Service.

REFUSE BALING AND PULVERISATION COMPOSTING IN ASIA

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INTRODUCTION

As the population of Asian nations continues to increase rapidly and as more people are concentrated in urban areas, the problem of solid wastes handling and treatment becomes more acute. Particularly in large metropolitan areas, the disposal problem has reached serious proportions in recent years due to the steady exhaustion of available dump of landfill areas and the impact of more rigid air, water, and land pollution controls. Due to the problems caused by the large and ever-increasing volume of refuse to be disposed of, the more stringent demands for environmental improvements and the rapidly rising cost of available refuse disposal schemes, some feasible methods of solid wastes handling and disposal are being carefully considered to ascertain the most appropriate handling and treatment approach necessary to cope with the solid wastes problems of Asian communities.

Some of the various schemes conceived for possible adoption are refuse baling, refuse pre-treatment by pulverisation and composting. Unlike composting with accompanying refuse preparation by pulverisation which has long been a traditional method of solid waste treatment in developing countries of Asia, the concept of applying baling to the solid waste field is relatively new and may present technical difficulties in certain cases.

REFUSE BALING

This method is known to have originated in Japan as indicated by FLINTOFF (1974), and is now being developed in several countries outside Asia. In this physical treatment, initial refuse volume is reduced by baling 7 or 8 times, and the bales which can weigh several tonnes may be heavy enough for disposal into the sea. The concept of ocean dumping is, however, not easily acceptable with the present conditions in Asia as there are less costly alternatives which completely preclude the possibility of marine pollution. It is highly questionable as to whether it will be necessary in the future. Nonetheless, the potential use of baling is being considered as one of the alternatives in solid waste handling and disposal which will enhance its capacity to facilitate long-distance transport because of the highly compacted and cohesive nature of the products and less space requirement.

Baling Process

Baling as defined by TALTY (1973) is the process of applying pressure to loose, compressible materials within an enclosure and binding the compacted mass while it is in a confined condition. The resulting material is known as a bale. The baling process is perhaps the simplest and most economical form of packaging. No encasing or wrapping is required to maintain the integrity of the bale and the cohesion of its contents. The compaction inherent in the process contributes to the conservation of space and consequently to economies in storage and transportation. In the scales on which they are produced on the farm and in the factory, bales are readily handled by manual or mechanical means. Typically, their surfaces are rectangular in shape and relatively smooth and they are to be stacked and nested economically without excessive wasted space. For these reasons, baling is often used in the packaging of certain types of raw materials, scrap, staple commodities, and manufactured products.

Types of Balers

Heavy types of balers are hydraulically or electrically operated. They are generally classified into 2 major types depending on the direction of the movement of the compressing ram:

Vertical stroke balers, which are sub-classified as down-stroke or up-stroke (so called 'pit' type) balers and horizontal stroke balers.

In vertical stroke balers, the materials are compressed between a moving ram (a piston with a flat face plate or 'platen' the size of one face of the bale) and the fixed floor or ceiling of the compression chamber. In the horizontal stroke balers, the ram moves laterally against the end of the bale being formed and in the process not only compresses the materials but also pushes the bales (the one being formed and one or more already completed) towards ejection through an elongated chamber and out at its open end. A typical multiple stroke baling press in Fig. 1 shows the 6 steps (A-F) involved in the operation. There is no available information whether the above types of balers are currently employed in the treatment of the refuse in the developing countries although there is scattered information that some baling plants are about to operate and others are still under construction. For example, the baling plant in mainland Hong Kong which costs about HK$16m (US$3.2m) as reported by WONG (1978) has a treatment capacity of 600 tonnes per day with a refuse reduction ratio of 5 to 1 and is expected to be in operation by the end of 1978. Another type of refuse compression plant

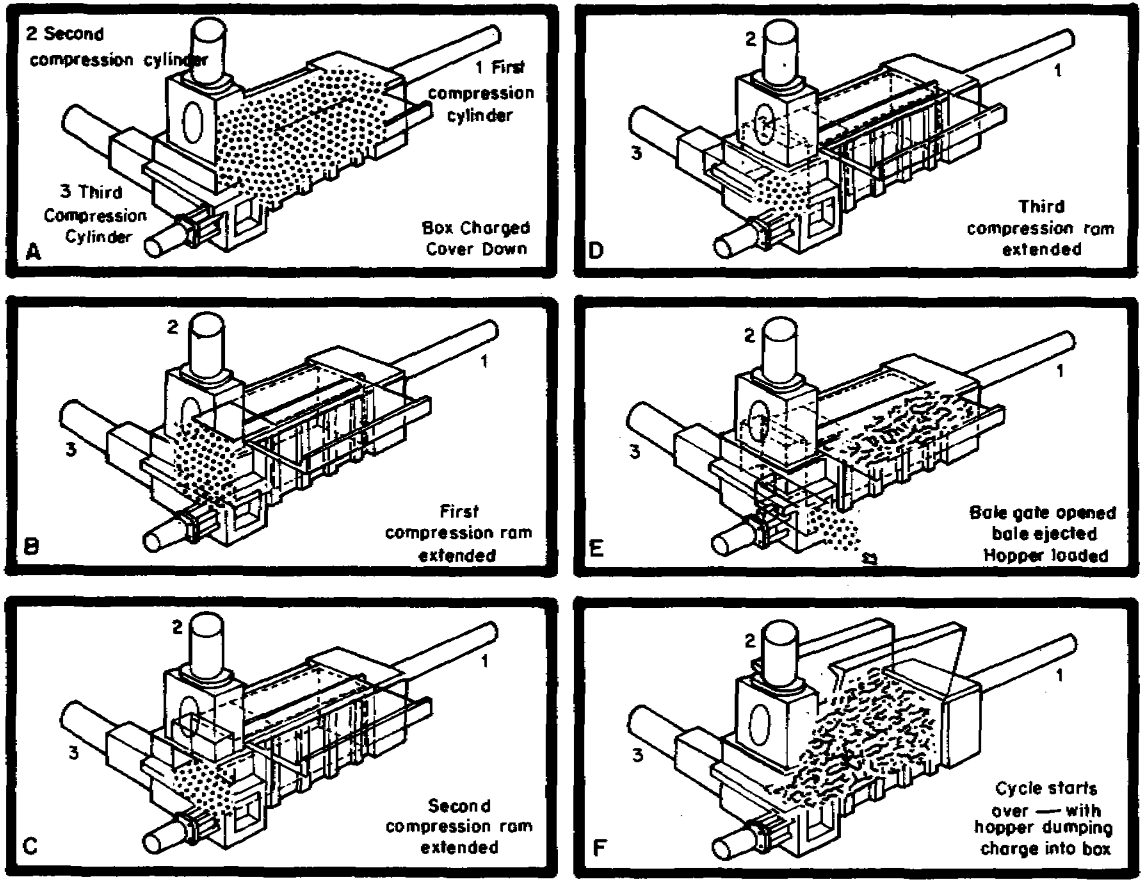


Fig. 1. Operation Cycle Multiple Stroke Baling Press

Source: Penn Central Transportation Company developed in Japan called the Tezuka Refuse Compression System APWARF (1969) is perhaps the most widely known baling process applied to refuse compaction in Asia. More or less comprehensive information about the key features and other relevant details of the system are provided in the following sections.

Tezuka Refuse Compression System

The compaction machine was developed by the Tezuka Kosan Company, Ltd., Japan, which spent 10 years of research on the development of the system. The compression system consists of 3 major operations namely:

1. The preliminary compression system.
2. The main compression system.
3. Equipment to add additional cover material such as asphalt or cement to the bales previously compressed within an enclosure such as chicken wire mesh.

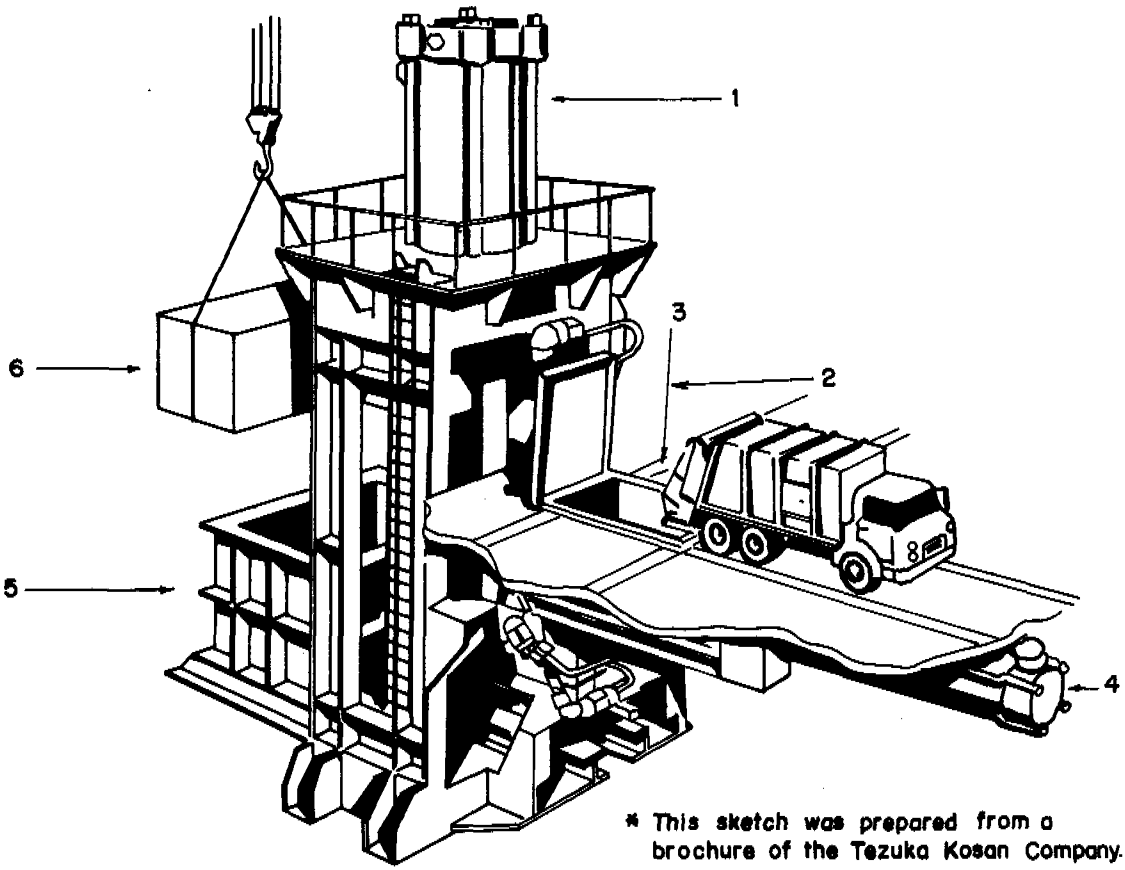
A sketch of the full scale of a Tezuka Refuse Compression Press is depicted in Fig. 2. Various types of preliminary compression systems are available, including one or two-stroke precompression devices which generally exert a pressure on the refuse in the system of about 15 atm (220 psi). The refuse leaves the precompression system and goes through a feeding hopper wherein further compression is attained; the maximum hopper pressure is about 29 atm (425 psi). From the loading hopper the refuse goes into the main compression system, which includes the main press, a mobile compression chamber, an associated bale enclosure, and a push-up device to remove the bale from the compression chamber.

The main ram and its pressure face are designed to perform 4 successive compression operations; the pressure face is divided into 3 sections. The dimensions of the latter range from 24.8 x 24.8 cm (63 x 63 in) to about 28 x 28 cm (71 x 71 in).

In the first step of the compression the full amount of the available force is applied to all 3 pressure face sections so that a pressure of approximately 46 atm (675 psi) is exerted on the refuse.

In the second step, a central cylinder about 46 cm. (18 in) in diameter and about 40 cm (16 in) in length is forced into the centre of the confined refuse: a nominal pressure of about 340 atm (5,000 psi) is exerted on the refuse beneath the cylinder head. The pressure face of the centre cylinder is only about 1/16th of the total area of the pressure face.

In the third step, 12 smaller cylinders distributed over the total original pressure face are pushed downward in either a simultaneous or individual pattern. Each of these 12 cylinders is about 17 cm (6.8 in) in diameter and about 46 cm (18 in) in length and exerts a pressure in excess of 340 atm (5,000 psi) on the refuse. The total pressure face



1. Main Press.
2. Hydraulically operated door of the precompression chamber.
3. Precompression chamber.
4. Ram of the precompression chamber press.
5. Main compression chamber moved out from under the main compression press.
6. Finished , enclosed bale being removed from the compression chamber.

Fig. 2. Full Scale Sketch of the Tezuka Refuse Compression Press.

area of these 12 cylinders is only about 11 per cent of the initial pressure phase area. In essence, then, a pressure of more than 340 atm (5,000 psi) is concentrated on small disconnected areas inside the bale.

In the fourth and final compression step the remainder of the original compression face is moved downward until an average pressure of about 55 atm (800 psi) is applied to refuse.

After compression process has been completed, the bale-enclosure closing device folds the enclosure used over the top of the bale; quite commonly chicken wire is used as enclosure of encasement for the bale. Operating time for the Tezuka system is about 10 to 15 minutes per 5-tonne bale. This does not include any additional time needed for bale treatment; additional treatment includes encasement of the bale in concrete, dipping of the bale into asphalt, wrapping the bale in vinyl or other materials, and strapping the bale with metal bands or mines. The density achieved according to Tezuka reports ranges from about 0.96 g/cm^3 to 1.92 g/cm^3 (60 to 120 lb/ft^3) with the variation resulting from variable composition of the compacted wastes.

The physical stability of these large refuse bales has not yet been established. The high densities of the refuse should be viewed in the light of the fact that the water content of the bales may be as high as 50 per cent. Although the manufacturer claims that aerobic bacteria activity is zero within the completed bale, certainly some partial degradation does take place. Fully enclosed, sealed, and moist bales could represent significant hazards, since anaerobic biodegradation could produce explosive methane gas. The volume reduction ratios claimed by Tezuka ranges from 5 to 1 to 7 to 1. Typical costs for the equipment alone may be estimated at roughly US$400,000 for 150 tonnes per day installation and at over US$7M for 3,000 tonnes per day installation. A 750 tonnes per day installation requires about 602 m^2 (720 yd^2) of space for the equipment alone, and a significant foundation must be placed beneath the press since it weighs approximately 400 tonnes. In addition to the 602 m^2 (720 yd^2) of space for the equipment itself, further area approximately 10 times that should be allotted for associated operations. In addition to capital costs, the operation cost requirements for a 750 tonnes per day installation are close to US$2 per tonne.

In view of the high cost of equipment, operation and maintenance requirements, the application of this system to the field of solid wastes treatment in developing countries of Asia is quite limited.

PREPARATION OF REFUSE FOR COMPOSTING (PULVERISATION)

Pulverisation of solid wastes in some developing countries of Asia is not normally performed for landfill purposes as their wastes contain few hollow articles and up to 80 per cent of the crude wastes as collected would pass a 50 mm screen (FLINTOFF, 1976). This as a matter of fact is almost as good as the average product of the hammer mill in Europe. In tropical regions, there may be bulky items of vegetable wastes yet size reduction is unnecessary as these types of wastes will ultimately decompose without pre-treatment of compostable wastes which contain a high proportion of materials that exceed 50 mm in size. This size reduction process does not only increase the surface area for contact between decomposable organic substances and attacking micro-organisms but also confers a secondary benefit by mixing the wastes into a more homogeneous material. Realising these advantages, Hong Kong authorities favoured the construction of a pulverisation/composting plant in Hong Kong Island which is now in progress and was expected to have commenced operations in February 1979. The plant had an estimated cost of HK$47.5M and an initial design capacity of 240 tonnes per day capable of extending to 480 tonnes per day with a refuse bulk reduction ratio of about 4 to 1.

Pulverisation Process

Pulverisation is a physical process of beating, shredding or subjecting refuse, to attrition with the purpose of reducing its volume and producing a material more suitable for further processing or disposal than crude refuse. Pulverisation methods commonly employed in developing countries of Asia as reported by FLINTOFF (1976) include the use of hammermills, rasps, short-term drums, long-term drums, shears and cutters, A general discussion on the types, principle of operation, throughputs, operational requirements and constraints encountered during their operation is given below while further details can be found in the appendix.

Hammermills

A hammermill is a strong metal casing carrying 1 or more rows of swing hammers on which is a mounted a rotating shaft, with a speed of several hundred revolutions per minute. It reduces the volume of refuse by the combined processes of impaction and shredding. Wastes are fed into the top opening of the machine and are reduced in size by being struck repeatedly by the hammers. Hammermills can be classified according to:

(1) Number of Rotor Machines (Figs. 3a and 3c)
   a) Single - consists of 1 rotor machine usually having a capacity of 45 m^3 per hour.
   b) Double - consists of 2 rotor machines with an output up to 90 m^3 per hour.

(2) Types of Hammer
   a) Swing - is composed of a horizontal rotor carrying fixed discs through which are pivoted groups of freely swinging hammer.

b) Fixed - is characterised by unidirectional rotors with hammers that are firmly wedged between discs attached to the rotor shafts.

(3) Kinds of Shaft

a) Vertical - employs lighter hammers, simpler in design and lower in cost.

b) Horizontal - employs a heavier hammer and can handle solid wastes containing large items but is more costly.

The capacity range for hammermills used for solid wastes is about 3 tonnes an hour to very large mills which can handle more than 10 times this amount. In practice, the range used in refuse pulverisation installations is generally from 5 to 30 tonnes per hour. The motor sizes range from 120 to over 400 hp.

The basic arrangement of a hammermill consists of a horizontal rotor carrying fixed discs through which are pivoted groups of freely swinging hammers; a frame or casing with an inlet above the hammers and an outlet area beneath. Impact plates and, in some cases, shredding teeth are fitted in the casing and a grate is usually fitted at the outlet area, the spacing of the grate bars determining the maximum particle size of product. Grate bar spacings from 6.3 to 10 cm (2.5 to 4 in) are used in primary mills for refuse treatment.

It is not possible to avoid hammermills becoming overloaded from time to time and it is usual to fit an electrical overload device which will halt in proper sequence the train handling elements. Installed power requirements are therefore relatively higher in hammermills as compared to other types of pulverisers because excess power must be allowed to deal with intermittent heavy loading.

For the reduction of urban solid wastes a hammermill can be of limited efficiency; a common level of performance is that only 85 per cent of the total pulverised refuse is below about 50 mm. For complete size reduction it would be necessary to provide 2-stage milling and screening, but for some reasons according to FLINTOFF (1976) it is rare to find this type of installation today.

The main operating costs of a hammermill are energy and hammer wear. Hammers are of two kinds: shaped steel castings of which the working faces are rebuilt daily or less frequently by welding; and rectangular hammers cut from standard sizes of steel bar. The second type was reported to cost less and is expendable after having been reversed end-to-end and top-to-bottom, and therefore, 4 cutting edges are utilised.

Pulverisation followed by compression offers the prospect of maximum volume reduction by physical methods, and could be of great importance in extending the economic radius of transport of refuse to distant disposal.

FLINTOFF (1976) reported that pulverisation of refuse by hammermills is growing in popularity for the following reasons:

(1) There is an increase in density which may reduce subsequent transport costs.

(2) Homogeneity is achieved by size reduction and thorough mixing and the refuse loses its characteristic of offensive appearance.

(3) Insect, rodent, and fire risks are very greatly reduced, if not eliminated.

(4) The ultimate structure of land reclaimed by means of this material is superior for both agriculture and building development.

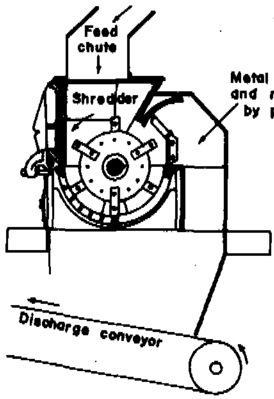
(5) The volume ultimately occupied by a given weight of pulverised refuse is only two-thirds that occupied by a similar weight of decomposed crude refuse.

Some of the more common hammermills which are commercially manufactured are the B.J.D. (British Jeffrey Diamond) crude refuse crusher, the Buhler pulverisers, Hazemag Novorotor mills and Buttner pulverisers. They are shown in Fig. 3. Further information about the physical and operational aspects of these hammermills is provided in the appendix.

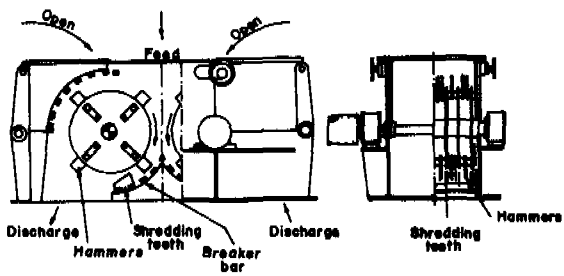
Two B.J.D. pulverisers are used in Manchester, England, to produce a fine material for tipping while a Buhler brand is employed in Switzerland. Hazemag and Buttner hammermills are used at several incineration plants in Germany and Holland.

All these hammermills, however, have a common operational constraint, that is the need to eliminate materials which may cause damage to or stoppage of the mill. To handle this operational difficulty, 2 widely used machines, the Gondard shown in Fig. 4 and Tollemache systems illustrated in Fig. 5 have been developed. They are designed specially to eliminate the need for pre-sorting the refuse, other than the removal of obviously oversized objects. A brief discussion of each system condensed from REINHARDT and HAM's (1974) report is given in the appendix.

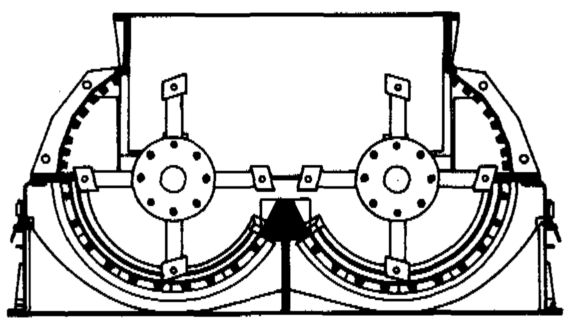
According to FLINTOFF and MILLARD (1968), 6 Gondard hammermills had already been commissioned in a 2-stage milling system in Haarlem, Holland. REINHARDT and HAM reported that a Tollemache mill had been initially installed at the Madison milling plant (USA) in 1969 primarily for testing purposes. Some of the common operational problems encountered in the operation of the Tollemache system are as follows:



a) Feed and Discharge Arrangements for the British Jeffrey Diamond Hammer Mill



b) Hazemag Novorotor Hammer Mill



c) Buhler Double-Rotor Hammer Mill

Fig. 3. Commercially Produced Hammer Mills

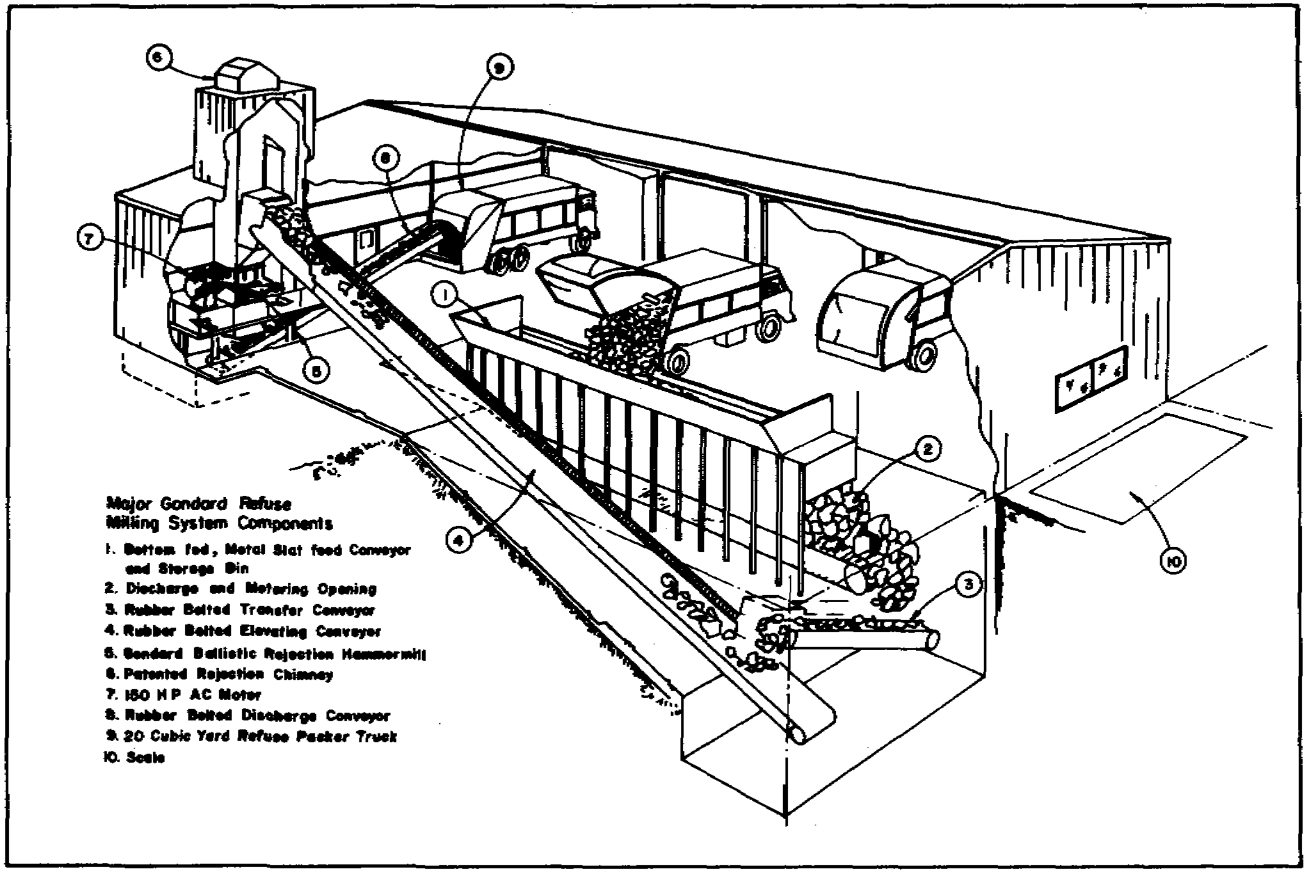


Fig. 4. Original Layout of Madison's Refuse Reduction Plant; Packer Truck being Loaded for Trip to Landfill

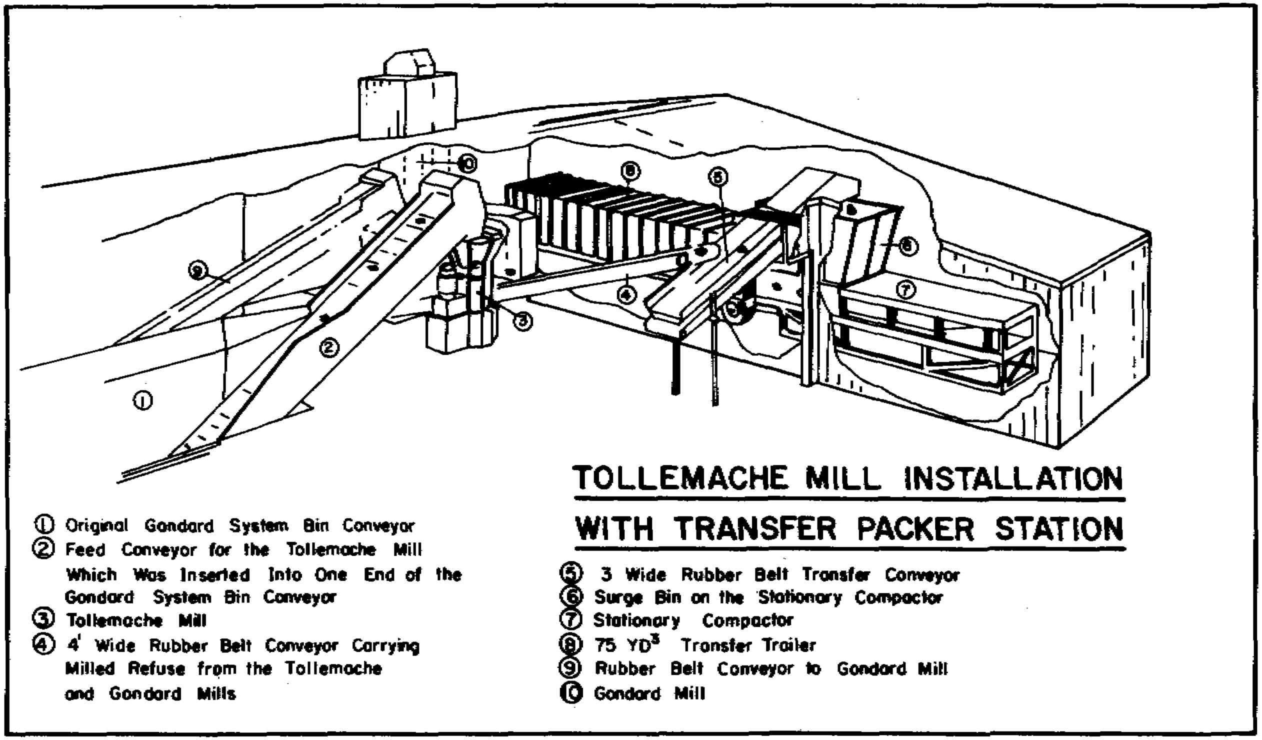


Fig. 5. Transfer Packer Station in the Tollemache System

(1) Feed delays due to excessive loading of the conveyor bins. The operator has to limit the amount of refuse placed in the bin to solve this problem.

(2) Failure of linkage in the speed reducer and occasional jamming of the belt when the objects become lodged between the conveyor rollers and trucks.

(3) Metal fatigue which can cause the hydraulic cylinder operating the hook that holds the trailer to the hopper to leak is one of the most serious problems usually encountered.

(4) Internal jams which usually occur in the grind section are brought about by heavy wire, bed springs, tyres, etc.

(5) Explosions - as the refuse is being processed a constant array of sparks is produced by contact of the hammers and metal in the refuse. If a can of paint thinner, an unbroken bottle of alcohol or a container with any other flammable liquid happens to enter the mill intact, an explosion is possible.

(6) Bearing problems - abnormal stress on the bearings usually causes burnout.

Drum-Type Pulveriser

The throughputs of drum-type pulverisers are usually flexible within limits. Operational difficulty normally encountered is the build-up of a roll of material in the drum. This roll consisting of textiles, plastics, etc., can weigh several kilograms and does not pass out with the rejects. Manual removal is a dirty and time-consuming task, as the machine has to be stopped. To eliminate this difficulty, a hinged plate through which the roll can be dropped is incorporated.

Rotating-Drum Machine Based on a 'Wet' Pulverising Principle

Rotating drum machines act on the principle of pulverising the refuse by attrition. The pulverisation process is achieved by the churning effect of the rotating drums. The amount of volumetric reduction is therefore a function of retention time within the drum. Some of the most common types of rotating-drum machines are the following:

Fermascreen: This is an octagonal or hexagonal-shaped drum which has in 1 unit the mixer, screen, and pulveriser. Each unit is designed as a batch-loading machine and pulverisation is carried out by tumbling action in the slowly rotating drum (1.6 rpm), the process being completed in approximately 2½ hours.

Seerdrum: A seerdrum differs from the Fermascreen in that it is designed on a continuous-flow principle. The drum is 2.4 m (8 ft) in diameter 8.8 m (29 ft) long and rotates at 11½ rpm. It is driven by two 30 hp motors, through reduction gearing and a ring gear on the drum. Pulverisation is brought about by the combined churning and shearing action of the deflection plates. The throughput capacity is approximately 5 tonnes/hour.

Operations require the moisture of the crude refuse must be raised to about 40 per cent by water sprays at the feed hopper. At this percentage the product has a density of about 532 kg/m^3.

Volund Pulveriser: This is basically a wet rotation process machine which includes further a pulverising element in the shape of beater arms, or paddles, on a central shaft rotating in opposite direction to the drum. The drum itself consists of 7 plates, the first section normally of 22 to 38 mm (7/8 in to 1½ in) in diameter to remove dust and other small materials which have been collected in the hoppers below. Pulverisation takes place mainly in the second section, where the contra-rotating blades break up the material as it is tumbled in the drum. The throughput is about 10 to 12 tonnes/hour.

Water at the rate of 50 gallons per tonne of crude refuse is added by means of sprays at the feed hoppers. Tin and ferrous metals are usually extracted from the feed conveyor by a magnetic separator before the refuse enters the pulveriser. The required moisture content is about 50 per cent while the density is expected to be approximately 532 kg/m^3. The drum is driven by a 30 hp motor and a 16 hp motor drives the beater arm shaft. The unit is a drum-type cylinder which rotates at 12 revolutions per minute (rpm) about the axis of the cylinder. This installation is common in Denmark.

Dutch Rasp: The Dorr-Oliver rasp sketched in Fig. 6 is one of the oldest machines for reducing refuse. It is used in several countries to process refuse for compost.

The rasp consists of a drum with 2 floors. The upper floor is perforated and is fitted with manganese steel pins. Radial arms hinged to the main vertical shaft sweep over the floor, rasping the refuse and forcing it through the perforation on to the collecting floor beneath. Non-reducible material is discharged through a special outlet. Operating speed is low (5 to 6 rpm) and power requirement is moderate, 80 hp The largest size of machine has a rated throughput of 8 to 10 tonnes per hour of crude refuse. While the pulverised product is of a consistent texture, the proportion of rejects is higher than with some other pulverising processes. Periodic replacement of the perforated plates is necessary, but otherwise maintenance costs are low.

Shears and Cutters: The methods of size reduction which have been considered so far are normally applied to 100 per cent of waste input, less salvage extracted, the justification for this being the physical character of the wastes, in terms of constituents and size, as established by analysis. There are some situations, however, in which size reduction is necessary only for certain specific wastes which form a small percentage of the total. It may be necessary to chop such wastes to facilitate mixing and decomposition, and a simple machine may be adequate for such a purpose. The chaff-cutter, with rotary blades turned by hand or a small motor is an effective low cost tool. A rapid reciprocating shear operating over a flat bed is another alternative; the blade, on which a heavy weight should be mounted, can be operated by a pair of cams.

An example of a shearing machine is the Von Roll shear illustrated in Fig. 7 which is specially designed for bulky waste. As can be observed from the figure, it consists of a V-shaped hopper wherein one face is fixed while the other moves on a pivot at the botton of the V, actuated by 2 double-acting hydraulic rams. The fixed plate has a number of slots 30 cm wide and 30 cm apart, with cutting blades at the edges of the slots. Corresponding blades on the movable plate shear the waste through the slots when the 2 plates are closed. Retaining teeth on both faces ensure that material is not pushed out at the top. The charging opening measures 3.4 m (11 ft 2 in) x 4 m (13 ft in). The installed power requirement is quite low since the shear is powered only by a 45 hp motor. However, an enormous force is still exerted due to the great leverage and slow movement. The potential throughput is in the range of 120-200 m^3 (157-260 yd^3). A shear of this kind is installed at an incineration plant in Geneva, Switzerland. The cost of the Von Roll shear is about US$40,000.

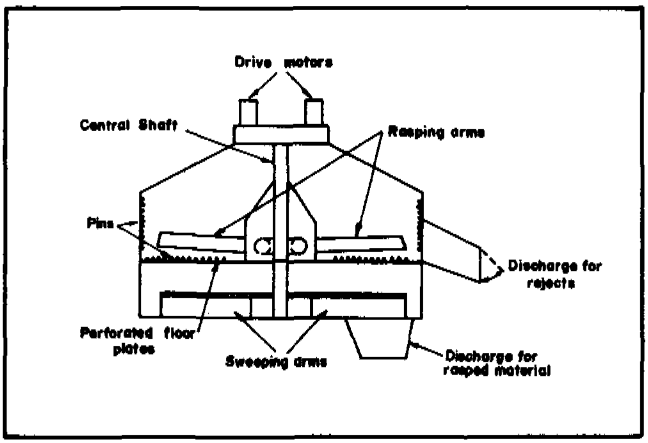


Fig. 6. Dutch Rasp

COMPOSTING

Composting is the biochemical degradation or reduction of organic matter into a sanitary, nuisance-free, humus-like material. For many centuries man has used leaf mould, animal manure, decayed fish and other decomposed organic matter in husbanding his crops. Farmers and

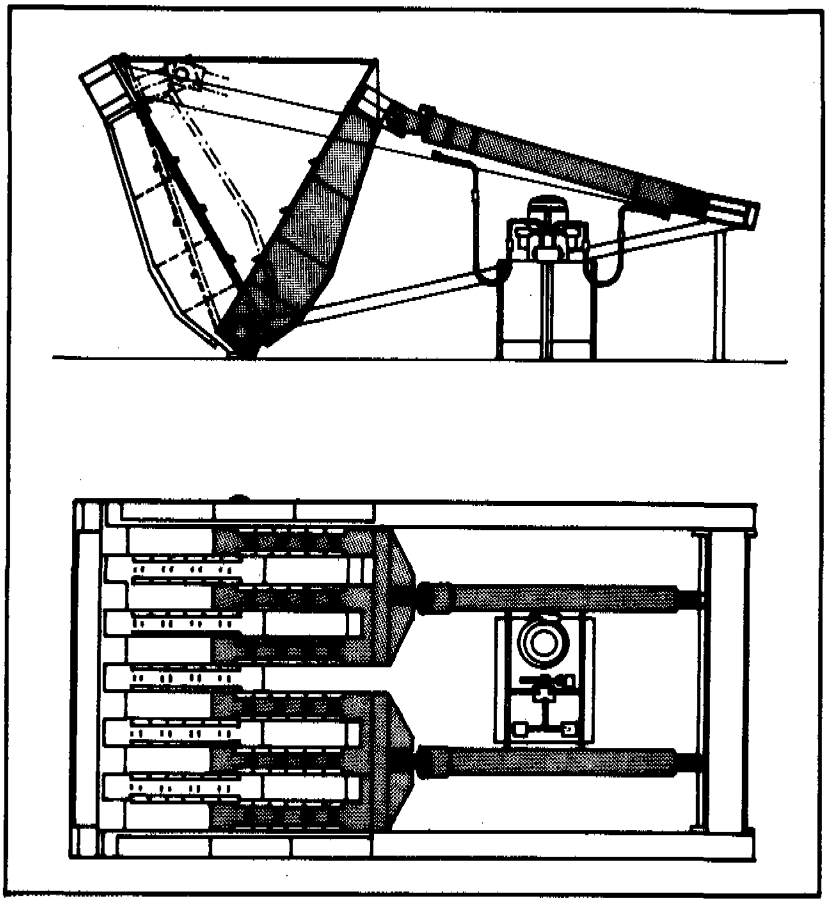


Fig. 7. Von Roll Shear

gardeners throughout the world have practised composting by placing vegetable matter and animal manure in piles or into pits for decomposition prior to use. The first significant development in composting as a systematised process took place in India in 1925. Sir Albert Howard FLINTOFF (1968) developed a process involving the anaerobic degradation of leaves, garbage, animal manures, and nightsoil for 6 months in pits or piles. The method, known as the Indore Process, was later modified to include more turning to hasten aerobic action. The Indian Council of Agriculture Research improved the method by laying down successive layers of refuse and nightsoil. This system is used under the name of the Bangalore Process.

Requirements for Successful Composting

Most often, the wastes of Asian countries are ideal for transformation into organic fertilizers because of their high vegetable putrescible content. Composting in these countries where high food production is of great importance is favoured by economic forces in as much as fertilizer imports are limited by foreign exchange constraints.

Asian experience in composting has revealed that at least 5 preconditions are necessary for successful operation. They are:

1. Suitability of the wastes.
2. A market for the product within 25 km of the compost source.
3. The support of agricultural authorities particularly by the Ministry or department of Agriculture.
4. A price for the product which is acceptable to most farmers.
5. A net disposal cost (plant costs minus income from sales) which can be sustained by the local authority.

When these conditions can be met, a developing country should closely study the possibility of composting because town wastes are a significant potential source of nitrogen, phosphate and potash as well as an organic soil supplement.

Methods of Composting

There are 2 general methods of composting: manual and mechanical.

The 2 manual methods of composting widely employed in Asia are the windrow (Figs. 8 and 9) and the Bangalore systems. The former involves the stacking of the wasted at ground level in separate heaps about 2 metres high or in continuous stacks about 4 metres wide by 2 metres high which are called windrows. Fermentation is initially aerobic, and a rapid temperature rise eliminates pathogens and insect larvae at the centre, but not in the outer layers. To enable aerobic fermentation to proceed, it is necessary to turn the windrow after several days, and to transfer the outer layer to the centre. If turned regularly, good

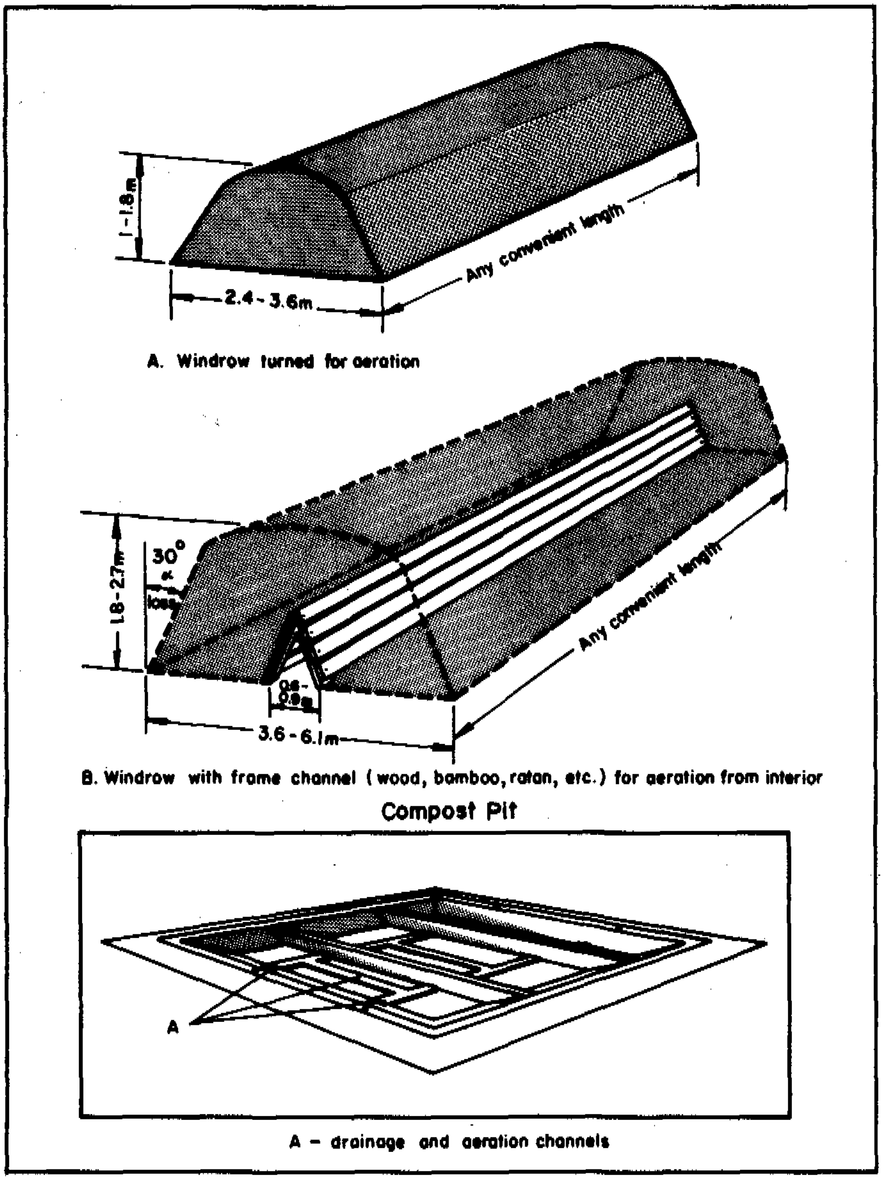


Fig. 8. Compost Windrows

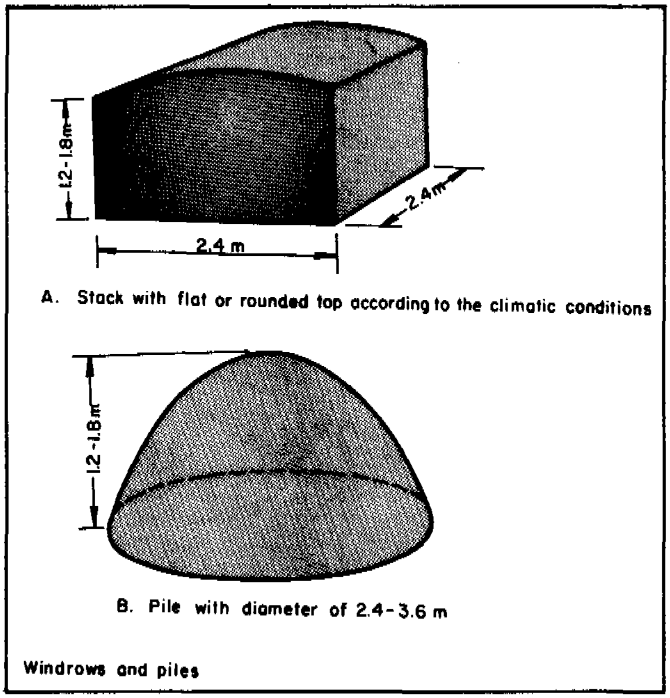


Fig. 9. Compost Stack and Pile in Windrow Composting

compost can be produced within a few weeks. The latter method is accomplished by depositing the wastes in trenches and leaving them undisturbed for a period of a few months to a year, after which the contents are dug out as compost. This method is often preferred when nightsoil is incorporated with town wastes, as the liquid is more easily contained. The long retention period of the Bangalore system is due to the fact that the decomposition is anaerobic and there is no temperature increase that can speed up bacterial activity.

A mechanical method drawn schematically in Fig. 10 is normally adapted in European countries not only because of high labour costs, but also because the process may be shorter in time and thus requires less space. At a typical plant, ferrous metals would be extracted magnetically and there might be hand-picking facilities for bottles. plastics, etc. Pulverisation may follow in order to break up larger constituents and to facilitate subsequent bacterial action by reduction of particle size and thorough mixing, The wastes next pass to the fermentation process which would be inside a closed container such as a large rotating cylinder or a silo with internal rotating paddles within which the wastes would be retained for several days when they are agitated and carefully controlled in respects of air supply, temperature and moisture content. Some systems provide further stages such as screening, ballistic separation, and secondary milling and drying to produce very fine product. With almost all systems the product is improved by being allowed to mature in large heaps for several weeks after the mechanical treatment has been completed.

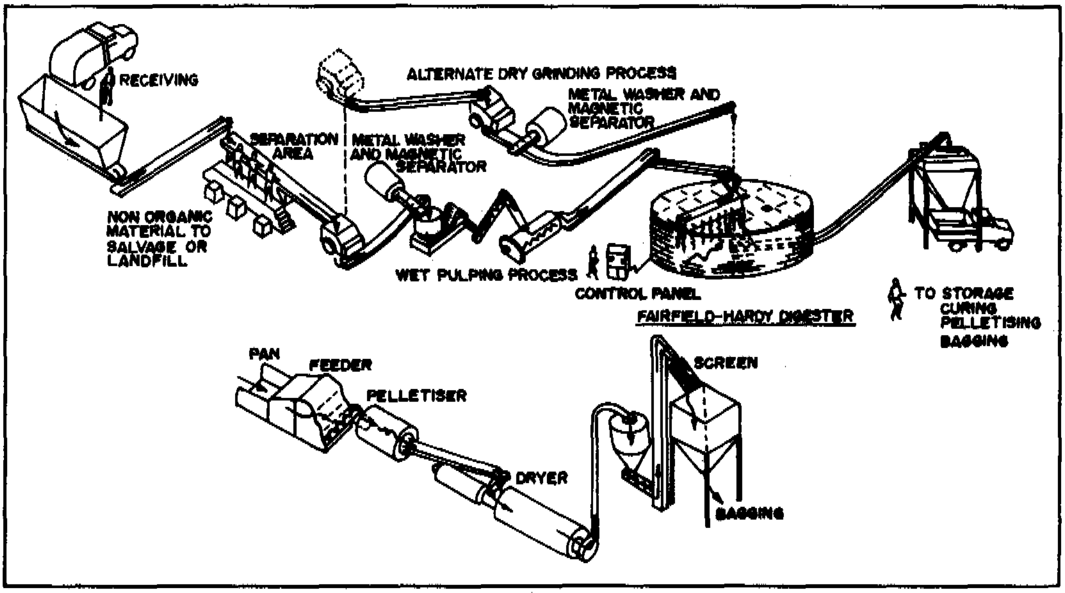


Fig. 10. Mechanical Compost Plant Flow Diagram

Plant requirements of mechanised composting systems are:

1. Reception and storage, usually deep bunker/grab crane;
2. Surge hopper supplying;
3. Picking belt, with overband magnet for removal of containers;
4. Pulveriser to reduce size, grind glass, and mix;
5. Fermentation and mixing in an enclosed vessel;
6. Screening to remove oversized elements from compost; and
7. Drying nutrient supplementation and bagging (optional)

USES/ADVANTAGES AND DISADVANTAGES OF COMPOSTING

The major advantage of composting is that refuse, a waste material, is converted into usable products. The products of both manual and mechanical systems have excellent qualities as organic soil conditioners and in some cases are also quite high in plant nutrients and therefore can be used as substitutes for commercial fertilizers.

The traditional manual method has the following disadvantages:

1. The products normally contain a proportion of stones, glass fragments, textiles and other 'contraries' which reduce their market value.
2. Large land areas are required, especially for the Bangalore process with its long retention time.
3. Some odour and insect problems are unavoidable.
4. Stacks and pits on unpaved areas are almost impossible to keep tidy.
5. Vehicle movement on unpaved areas is difficult after heavy rains.
6. The system sometimes poses health risks for the workers.

Due to these reasons, the traditional manual composting methods can seldom be applied in large cities.

For mechanical methods, the following disadvantages render them not feasible to use in developing countries at present:

1. High capital and operating cost (cost of heavy equipment, operation, and maintenance).
2. High energy consumption (a pulveriser of 20 tonnes/hour requires a 300 hp motor).
3. Loss of volatile nutrients through ventilation in fermentation vessels.

The fact that mechanised composting plants were originally designed for European wastes and labour costs, their adaption requires that every element must be carefully evaluated in relation to Asian conditions.

Partial Mechanisation of Traditional Composting Methods

In the techniques of composting, there is a wide gap between the traditional, cheap manual methods, widely and successfully used in small towns (but inappropriate to large cities) and the complex and expensive mechanical composting plants which have been developed for European wastes high in 'contrary' materials. A recent study of this problem for a large city in India has come up with a proposal that may fill this gap: a composting system which is based on traditional Asian methods but which by means of a limited investment in civil engineering work and mechanical plant, reduces substantially the area of land required and operates at an acceptable cost. The proposal has made recommendations on the required throughput, removal equipment, transport of products, land requirement and quantity of water supply for a given population. The net income is calculated on the basis of computed cost per tonne of waste disposed and the mean selling price of compost (Rs 35/tonne) (US$4.4/tonne) produced. The major requirements are summarised in Table 1.

Table 1. Mechanised Traditional Composting Plant Requirements

Population	100,000	200,000	500,000
Plant capacity (tonnes/day	40*	80	200
Removal capacity (trailer loads/day	-	20	50
Removal Equipment:			
a) tractor shovels	-	½	2
b) towing tractors	-	1	2
c) trailers of 6 m^3	-	2	4
Transport of Products:			
a) trailers	1	3	6
b) towing tractors	2	1	2
Water requirement, m^3/day	20	100	100
Land requirement, ha	0.7	1.5	3

*Note: The 40 tonne/day plant capacity utilises the traditional manual method of composting.

A comparison in costs of plants of varying sizes is also given in Table 2 for 40, 80 and 200-tonne plant capacities.

Table 2. Comparative Costs of Composting Plants of Varying Sizes

Population	100,000	200,000	500,000
Plant capacity (tonnes/day)	40	80	200
Capital cost, Rs	650,000	3,350,000	7,500,000
Annual cost, Rs	367,000	891,000	2,060,000
Waste disposal cost, Rs			
Gross/tonne	31	38	34
Net/tonne	16	20	16

COMPOSTING PRACTICES IN ASIA

There are at least 3 composting systems employed in Asia, namely: the Bangalore (Indore) process which is common in India, the Jersey, (also known as the John Thompson system) in Bangkok, Thailand, and the T.A. Crane BREIDENBACH (1971) process practised in Kobe, Japan.

The Bangalore composting system is characterised by a trench in the ground, 2 to 3 feet deep. The materials are placed in alternated layers of refuse, nightsoil, earth, straw, etc. No grinding is necessary and the pile is turned by hand as often as possible. The detention time is about 120 to 180 days. The process is able to compost only 30 tonnes per day and about 700 tonnes collected. The product is excellent, but the process is untidy and may involve health risks for workers through skin contact. The selling price is about US$3/tonne. Farmers near Bangalore collect about 100 tonnes per day of raw waste which they compost themselves and they also dig partly decomposed wastes from the dump, as is also done in Kathmandu.

It was realised lately that conventional methods of composting require a large space for trenching operations and the preparation of the compost which takes about 4 to 6 months can be considerably reduced. Moreover, considering the fact that these operations are not successful during rainy months and also the compost prepared is of low nutrient value, it was decided according to the report of BUTT, et al (1974) to set up mechanical compost plants in India. The land requirement for the mechanical compost plant is considerably less and the preparation of compost takes only about 4 weeks. By mixing sewage sludge with refuse in these urban centres (all of which are sewered) compost of not less than 3 per cent NPK value could be prepared. Realising these advantages, New Delhi had previously conceived the installation of a mechanical composting plant, initially for about 200 tonnes/day.

The compost plant at Din-Dang, Bangkok, Thailand, constructed in 1961 has a capacity of composting 150 tonnes (450 m^3/day) of refuse per day. The plant is a 'Jersey' system type and includes a receiving ramp for 4 trucks at a time, 2 shredders, magnetic scrap separators, centrifugal separators and belt conveyor lines and the fermentation house. The fermentation house has 6 floors each 300 m^2 in area. The contents of each floor are dropped to the next lower floor daily to effect 6 days detention time and a daily output of 210 m^3 or 70 tonnes of compost. The compost is saleable and makes about 0.8 million baht (US$40,000) worth of compost annually. However, the uncomposted portion of the refuse is still very large and the open dumps are posing a great public health hazard. Two more plants had been built at a capital cost of about US$4 million for 300 tonnes/day capacity at 1968 prices.

In Kobe, Japan, there is a continuous-flow 3-stage horizontal mechanical digester plant (T.A. Crane Process) in which composting is followed by 2 days of curing with forced air. The prototype 20-tonne a day plant, constructed in late 1956, is adjacent to an old incinerator and the nightsoil transfer station. Domestic refuse is put on a device that feeds it in uniform amounts on to a picking belt. After passing through a vertical swing hammer grinder, the refuse is conveyed to a mixer where about two-thirds of the refuse, by weight is mixed with about one-third nightsoil containing 94 per cent moisture. Material is kept aerobic by forced air and continuous slow stirring. After 48 hours in the digester, it is cured and dried for 48 hours in a porous bottom curing bin in which forced air is used.

In Manila, Philippines, solid waste disposal as outlined by ESPIRITU and DRAN (1978) is carried out by in-place composting in a landfill. In this process the shredded refuse slowly but completely compost in-place by provision for the aerobic process being made for by blowing air into the landfill under a pressure of 10.16 to 25.4 cm (4 to 10 inches) of water. Before the landfilling of the shredded refuse begins, a perforated pipe is placed in the ground in hollow trenches. The small pipe would be approximately 1.6 cm in diameter laid about 3 metres on centres, these would be connected to air blowers. Air is blown intermittently through the shredded and compacted refuse. The amount of air used is dependent on the speed with which the breakdown occurs. Soon after the process begins, the temperature rises sharply and residual odours quickly disappear. Fly larvae are killed and thus fly breeding is prevented. In a matter of 1 to 3 months the material is stabilised into a finished compost.

In Jakarta, Indonesia, the crude refuse (about more than half the collected wastes) is sold to the farmers at US$0.50/tonne delivered. The farmers apply the material raw to arable and fruit crops.

At Kurungula, Sri Lanka, which has a population of 25,000, aerobic windrow composting is practised, turning at monthly intervals for several months, nightsoil being incorporated. The procedure is experimental and suffers anaerobic lapses, perhaps because of excessive nightsoil or because the windrows are too small to retain the heat. The product was sold for US$1.50/$m^3$, but for some reasons the sales eventually ceased.

In Dehiwela, Mt. Lavinia, Sri Lanka, a well-managed trenching ground is at work. It appeared that such grounds could be kept in perpetual rotation if converted to Bangalore composting by increasing the size of the trench, mixing town wastes with the nightsoil and selling contents of the trench after 6 to 12 months.

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REFERENCES

American Public Works Association Research Foundation, APWARF (1969) The Tezuka Refuse Compression System, A Preliminary Report, U.S. Department of Health, Education, and Welfare., US Public Health Service.

Breidenbach, A.W., (1971) Composting of Municipal Solid Wastes in the United States., US Environmental Protection Agency.

Butt, M., Swamy, T.S., Chatterjill and Rijlani, H.U., (1974) Country Report on India, World Health Organisation, Regional Seminar on Solid Wastes Management, Bangkok, Thailand, November.

Espiritu, J.H. and Dran, C., (1978) Solid Waste Management Report on Metropolitan Manila Experience.

Flintoff, F., (1974) Present State of Knowledge on and Trends in Solid Wastes Management, Solid Wastes Management in Southeast Asia, World Health Organisation, Report and Working Papers of Regional Seminar, Bangkok, Thailand, November.

Flintoff, F., (1976) Management of Solid Wastes in Developing Countries, World Health Organisation Regional Publication Southeast Asia Series No. 1.

Flintoff, F. and Millard, R., (1968) Public Cleansing, Refuse Storage, Collection, and Disposal, Street Cleansing, Mclaren and Sons, London.

Institute for Solid Wastes of American Public Works Association, (1970) Municipal Refuse Disposal, Interstate Printers and Publishers, Inc., Danville, Illinois.

Reinhardt, J.J. and Ham, R.K., (1974) Solid Waste Milling and Disposal on Land Without Cover, Volume 1, Summary and Major Findings, US Environmental Protection Agency.

Talty, J.T., (1973) Baling Solid Waste to Conserve Sanitary Landfill Space, A Feasibility Study, Environmental Protection Agency Office of Solid Waste Management Programs.

Wong, M.K., (1978) Controlled Tipping in Hong Kong.

APPENDIX

PULVERISING EQUIPMENT DETAILS: FLINTOFF MILLARD (1968), REINHARDT HAM (1974)

1. The B.J.D. (British Jeffrey Diamond) crude refuse crusher is basically a heavy duty swing hammermill incorporating specially designed hammers, each weighing over 50 kg which introduce an exceptionally high degree of shear, normally absent in conventional hammermills. The crusher will have feed openings up to 1.2 x 2.3 m (48 x 90 in) which will accept most materials from the municipal refuse. Within the limits of 200 to 300 of installed horsepower, the machines are capable of reducing normal town refuse to nominal 7.6 cm (3 in) product suitable for tipping, at the rate of 30 to 50 tonnes per hour (i.e. 6 to 6.5 hp per tonne per hour processed, compared with 10 hp on conventional hammermills).

2. The Buhler pulverisers have separate cast steel hammer heads fixed to the swing arms. The upper sections of the casing are lined with the milling bars and the pulverised materials leave the machine through grate sections. Two-62 hp motors are used with a single rotor machine to provide the required high starting torque. When normal running speed has been attained (1,200 rpm) one motor automatically cuts out. Capacity of the single rotor mill is approximately 45 m^3 (59 yd^3) per hour. The large double rotor machine is powered by two-100 hp motors and has an output up to 90 m^3 (118 yd^3) per hour. Buhler also produces a small double rotor mill for secondary grinding.

3. Hazemag Novorotor mills reduce the volume of the refuse by the action of the high peripheral speed of the hammers (rotor speed up to 300 rpm) which crush and tear the refuse over impact bars and shredding teeth in the casing. The refuse is ground to quite small particle size (under 5 cm) (2 in) but if a coarser product is acceptable, hammer speed can be reduced with consequent saving in power and hammer wear. Hazemag mills are produced in a range of sizes with capacities approximately 40 to 250 m^3 (52 to 330 yd^3) per hour.

4. The Buttner pulveriser is a double-rotor machine with unidirectional rotors, and differs from conventional hammermills in several respects. The hammers are not pivoted as swing hammers but are firmly wedged between discs attached to the rotor shafts. Each hammer has 4 beating surfaces and is reversible in 3 times. Refuse is fed through the top opening on the first rotor. It is partly crushed off by the hammer and swings against an impact plate with great force. The material is then thrown towards the second rotor and a second stage reduction takes place between this rotor and an impact surface consisting of a second impact

plate in the upper part of the casing and an adjustable lower one. There is no grate, so no risk of moist refuse choking the machine. The size of the product can be varied by adjustment of the lower impact plate and speed of the rotors. The latter normally runs at slightly differential speeds (1,480 and 1,500 rpm respectively) the peripheral speeds of the hammers being approximately 69 km/hr (63 ft/sec). Each rotor is driven through V-belts by independent motors. The largest size machine has a rated capacity of about 63 m^3 per hour and is powered by 2 80 hp motors.

All of these hammermills have a common operational constraint, that is, the need to eliminate materials which may cause damage to or stoppage of the mill. To handle this operational difficulty, 2 widely used machines, the Gondard and the Tollemache systems are developed. They are designed specially to eliminate the need for pre-sorting the refuse, other than the removal of obviously oversized objects. A brief discussion of each system condensed from REINHARDT and HAM (1974) follows:

Gondard Equipment: The improved version of Gondard hammermill (Fig. 4) consists of a horizontal main shaft with 48 3.01 x 10.16 x 27.94 cm (1-3/16 x 4 x 11 in) swing hammers on 4 shafts. The 6.8 kg (15 lb) hammers are driven at 1,150 rpm by a 150 hp motor. a patented chimney is included to permit ballistic rejection of large, unmillable objects. Ballistic rejection occurs when such objects are struck by the hammer sufficiently hard that they pass the 8.23 m (27 ft) length of the chute, strike a deflection plate, and come down a separate chute. This feature allows ungrindable objects to bypass the grates through which milled materials leave the mill.

The reduction plant employing a Gondard hammermill is designed to minimise floor space. This design leads to complex system of 3 feeding conveyors. The motors for the 3 conveyors are controlled by the special unit that allows the operator to vary the speed of the speed of the 2 rubber-belt conveyors or the conveyor in the 57.39 m^3 feed bin. The mill also includes a system to stop all 3 conveyors when power input to the mill motor exceeds 125 per cent of rated load for 5 consecutive seconds.

The crude refuse is fed into the mill in the direction of hammer rotation and at a point on the upswing of the hammers. Heavy and bulky objects such as tyres and large pieces of metal, are struck by the hammers and thrown up the chute. Very light materials, such as nylon, stockings and plastics tend to become entangled with these heavier items and are carried up with them. The rejects are returned to ground level by means of another chute connecting to the hopper at the top of the reject chute. Rejects generally amount to about 5 per cent (by weight) of the crude refuse. The normal throughput of Gondard machine ranges from 10 to 15 tonnes per hour depending in the size of grates used.

Tollemache System: The Tollemache mill (Fig. 5) is a vertical shaft, ballistic rejection hammermill. It has funnel-shaped outside walls and a rotor which has the shape of a conical surface when spinning. The rotor is driven at 1,350 rpm by a 200 h.p. squirrel cage motor powered by a 3-phase 440 volt source.

The hammers are connected to the rotor in 3 distinct layers. The hammers in the top layer are mounted to the shortest radius; the diameter to the hammer tips is 83.82 cm (33 in). This layer, a pre-break section, is also the site of ballistic rejection of some potentially damaging and unmillable materials.

From the pre-break section, the refuse falls into the constricted neck of the mill; which has a diameter of 104.1 cm (41 in). The hammer tip diameter in this layer is 96.52 cm (38 in). In this section therefore, there are only 3.81 cm (1½ in) of clearance; thus any material that is ungrindable or that has not been sufficiently reduced in size to pass this restriction will be spun around the funnel and will exit through the rejection chute opposite the feed opening.

The material then enters the grind section, where the hammers have a 109.22 cm (43 in) tip diameter. It is here that most is done to produce the desired particle size. The ground material is discharged centrifugally through an opening at the bottom of the machine.

Two layers of metal form the housing of the mill. The outer layer is the shell of the unit. The inner layer is a removable protective lining upon which are mounted breaker bars. It is the action between the rapidly moving hammers and the stationary bars that produces the grinding.

The Tollemache mill has 34 hammers which are 25.4 cm (10 in) in length, 10.16 cm (4 in) in width and 3.016 cm (1-3/16 in) in thickness and each weighs 6.81 kg (15 lb). It is fed by a metal flight conveyor system. The one piece, 1.14 m (45 in) wide conveyor is driven by a 28 hp motor, equipped with a speed reducing mechanism and overload section. The 5.49 m (18 ft) long horizontal portion of the conveyor is located in the Gondard storage bin and over approximately one half the length of the portion of the Gondard feed conveyor lies within the bin. The inclined portion of the feed conveyor is about 45^{o} to the horizontal. The variable drive mechanism allows the operator to adjust conveyor speed from 244 m/min to 3.66 m/min. An automatic overload stops feed conveyor when the mill motor draws 100 per cent of its rated capacity. The conveyor restarts automatically after the mill motor draws less than 75 per cent of its rated capacity for 5 consecutive seconds.

MECHANICAL PROCESSING AND COMPOSTING

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INTRODUCTION

Mechanical processing and composting are options available in municipal waste management which have in common that, within the total spectrum of alternative treatment methods, they fall somewhere between landfilling and thermal treatment, at least with regard to the level of cost and the degree of volume reduction achievable.

This general statement need not of course apply in each and every situation. It merely indicates that if one wants or has to undertake more than simple landfilling, e.g. in the case of scarcity of landfill space and for special environmental requirements, but does not wish to resort to drastic volume reduction through incineration or other forms of thermal treatment combined with energy recovery, one may consider some form of mechanical processing or composting.

The types of processes available in this category are (among others): baling, shredding, and mixing/screening as pretreatment methods to improve conditions for subsequent transfer and haul and/or landfill operations, and: composting and mechanical sorting as main treatment processes to be combined with residue landfilling; plus a variety of combinations of the above processes.

While the first methods are merely designed to change some of the less desirable properties of solid wastes such as inhomogeneity and low density, the latter go beyond disposal and aim at waste utilisation/resource recovery.

BALING

Compared to other methods, baling of municipal solid wastes represents a fairly recent development. Thus information on long-term, full-scale operation is still limited. However, it seems as though baling has not spread as widely as was envisaged at least by some experts when the first optimistic reports were published some 5 years ago. The basic idea of baling is to provide for maintained volume reduction through compaction prior to transport and landfill operations.

There are various alternative baling concepts and installations available:

- with or without shredding prior to baling,
- with or without wiring to hold bales together,
- with or without covering or coating of bales as a final process step.

To mention the names of just 3 different systems available:

i) Tezuka, Japan; high pressure baling without pretreatment, bales being covered with wire-netting and coated with asphalt (other types available too).

ii) American Hoist and Derrick, USA; high pressure baling, no pretreatment, no wiring or coating.

iii) Lindemann, Federal Republic of Germany; shredding prior to baling at lower pressure, baling straps required.

The bale volumes are of the order of 1.5-2.0 m^3 with densities between 0.8 and 1.2 t/m^3.

The costs for baling can be roughly estimated on the basis of the following example:

Investment cost for a 30-40 t/h plant, including mobile equipment for on-site transportation of bales; land and site development costs excluded: 5-6 million DM (US$2.6-3.2 million).

Costs per tonne of waste baled

1 shift operation (70,000 - 75,000 t/a)	14-16 DM
1 shift operation (150,000 t/a)	10-12 DM

The above cost information applies to the American Hoist and Derrick system as well as to the Lindemann system, since the high pressure baler costs about the same as a shredder plus a low pressure baler. A Tezuka plant, however, would involve substantially higher costs, but produces coated bales of slightly higher density.

In general, baling may be considered if waste arisings exceed 50,000 t/a and if the advantages of long distance hauling (usually only if more than 30 km) of bales can be combined with the advantages of being able to just stack the bales e.g. under certain restricting landfill site conditions, instead of tipping, spreading, compacting and covering untreated waste, as in the case of a normal landfill operation.

On the other hand, it is obvious that baling is only applicable for certain types of wastes, namely voluminous, low density and low-moisture wastes.

Such waste characteristics, however, should make the responsible authorities think twice before deciding for a conventional disposal system instead of an alternative oriented more towards resource recovery. In other words, wastes best suited to baling are also likely to be amenable to other advanced treatment alternatives.

SHREDDING

Shredding is another method of reducing waste volume and at the same time producing a more homogenous material. Some types of application are:

- Shredding prior to landfilling, shredding plant on landfill site. Purpose: to improve landfill operation, shredded waste easier to place and to compact, more acceptable appearance of site even without daily cover; easier control of vectors and burning.
- Shredding prior to transfer and haul operations, (plant located at transfer station). Purpose: volume reduction for more economic transport, shredded waste easier to handle by conveyor belts, compaction and other mechanical equipment.
- Shredding as a pretreatment process prior to any further mechanical (e.g. scrap separation), thermal or biological (composting) treatment with the shredding plant located at the same site as subsequent treatment installations, or at another site.

In the latter case, one would normally not refer to a shredding plant with subsequent further processing, but rather to a plant including shredding among other processing steps. This was done, however, to indicate that shredding lends itself readily to forming the first step in a staged development of a potentially complex waste management system.

In this respect the potential of shredding far exceeds that of baling.

From the wide variety of equipment available, at least the following should be mentioned:

* fast type
    - horizontal and vertical shaft hammer mills (the latter of which seem to offer certain advantages);
    - crushers, mostly derived from rock or ore processing.
* slow type
    - cutting-shearing drums;
    - rasp mills (e.g. "Dorr-Oliver Rasp");
    - ball mills (e.g. "Loesche Cascade Mill").

It is interesting to note that none of the aforementioned, except for the Dorr-Oliver Rasp, have been originally developed to process municipal waste but have been derived from other (more profitable) areas of mechanical processing. So far, hammer mills of different types seem to be most commonly used for solid waste shredding, especially those equipped with special rejection mechanisms to remove non-reduceable materials before they enter the milling section, where they might cause jamming or damage to the equipment. During the last few years - at least in Germany - the advantages of the slower type installations have been recognised: less noise, dust and danger of explosions. On the other hand there is still less well-established information available on the performance of these than on conventional hammer mill operation.

Although there are far more shredding installations in operation than baling plants, it seems to be more difficult to give cost information on shredding than on baling. This may be because there is a wider variety of shredders and also due to some additional inter-dependent factors: wear and energy consumption vary substantially with fineness of end product as well as with waste composition. For instance the presence of abrasive residues (cinder) from household coal burning can increase hammer wear by 50 per cent or more. Based on average German conditions with regard to waste composition, a hammer mill plant producing an end product of about 50 per cent by weight below 50 mm and 90 per cent below 100 mm particle size (sufficient for landfilling), designed for a throughput of 20 t/h would cost:

Investment cost (land cost excluded)	2-3 million DM
Cost per tonne of waste shredded for:	
1. shift operation (30,000-35,000 t/a)	16-19 DM
2. shift operation (∿75,000 t/a)	11-13 DM

and for a 2 mill plant (2 x 20 t/h):

Investment cost	3.2-4.5 million DM
Cost per tonne of waste shredded for:	
1. shift operation (60,000-70,000 t/a)	12-14 DM
2. shift operation (∿150,000 t/a)	9-11 DM

A shredding plant based on a cutting-shearing drum would cost about the same, or perhaps slightly on the lower side, and would be preferable in cases where more of a cutting size reduction instead of crushing is required, depending on waste composition.

A ball mill (e.g. "Loesche Cascade Mill") would require substantially higher investment costs but would offer the possible advantage of producing finer material if desired and having the additional capability of serving as a mixing unit, e.g. to admix sludge.

It is a matter of debate as to whether or not the advantages of solid waste shredding can justify the cost and effort. After some 20 shredding plants were built in Germany during the 1960's, the present thinking in that country is that normally in the case where landfilling is the main disposal method, shredding is unnecessary since heavy compaction equipment (steel wheel compactors) is available with which nearly the same density can be achieved in the completed landfill, if built up in thin layers. Shredding seems to have developed more widely in other European countries, e.g. in Great Britain and Scandinavia, where it is widely used, especially in combination with transfer stations. In some cases, this is because of the advantages in gaining public acceptance.

The final remarks with regard to baling also apply here: if waste quality and quantity makes shredding worthwhile it may at the same time justify further steps aimed at recovery and use of some part of the waste.

OTHER PRETREATMENT METHODS

There are some other methods of mechanical pretreatment of solid wastes combined with landfilling, which should at least be (briefly) mentioned:

- Screening, to produce a fine fraction to serve as cover material for the landfill (usually revolving screens).
- Mixing, to homogenise wastes, admix sludges etc.; trommel-type mixers are preferable, which also provide for some grinding, possibly combined with a trommel screen attached to the discharge end.
- Materials separation, e.g. magnetic separation of ferrous scrap (if many or all recoverable materials were separated one would of course not talk about a pretreatment method for landfilling; see other papers dealing with resource recovery).

Examples of equipment designed for the purpose of mixing and screening prior to landfilling are:

- "Dano Egsetor" mixing/screening/grinding trommel by Bias, Denmark;
- "Vickers Seerdrum", by Vickers, U.K.
- Mixing/Screening trommel by Bühler, Switzerland.

These methods are not yet - or with regard to the mentioned Dano and Vickers equipment - no longer used as widely in Europe as they deserve.

Pretreatment through mixing and/or screening can provide for substantial improvement in landfill operations and especially public acceptance, while costing about 10-30 per cent less than shredding.

COMPOSTING

It is not necessarily a large step from landfill with mechanical pretreatment, to solid waste composting. In fact composting, as a natural process, takes place in all landfills and anywhere where bio-degradable organic materials are stockpiled, provided there is no lack of moisture and air (oxygen) and no absolute sterility. The principal difference between a landfill and composting plant is that the product of biological decomposition is used in the case of a composting plant and wasted in the case of a landfill. Of course, composting takes place in the surface layers only of a landfill. Below, in the absence of air, anaerobic decomposition takes place, a process to be avoided in composting plants.

So a landfill, especially one combined with a shredding plant, could be easily turned into a composting plant just by leaving the material uncompacted on the surface for a certain period of time, for instance 6 months, digging it up again, and screening out what might be called compost.

Although this may well be a reasonable approach, at least for starting towards composting, a proper plant goes beyond this and consists usually of the following 3 processing sections:

- mechanical pretreatment such as shredding, screening, mixing (e.g. admixing of sewage sludges), magnetic separation etc;
- composting process, i.e. controlling the process by providing for optimal air and moisture supply, preventing heat losses etc;
- subsequent mechanical treatment such as screening, shredding, air classification (for separation of glass and other heavy, inert materials from the compost) and refinement of end product, e.g. admixing of fertilizer etc;

It is mostly in the second of these sections where proprietary systems have been developed, while the design of the first process section would usually depend on local conditions and requirements with regard to waste composition, and the third section on local requirements with regard to product quality.

When composting is to be taken into consideration in waste management, one should first determine what portion of the solid waste is suitable for this treatment method and thereby to derive what could be achieved by composting in terms of waste volume reduction and production of useful materials.

Household waste components mainly suitable for composting are:

- organic kitchen wastes (food wastes)
- organic garden wastes (except wood)
- paper and cardboard.

These components usually represent between 40 and 60 per cent by weight of European domestic wastes. Composting should in any case be excluded if the above mentioned components add up to less than 30 per cent of the waste mixture to be treated.

Based on the usual 40-60 per cent of waste components suitable for composting the product/residue balances can vary within the following ranges:

Table 1. Product/Residue Balances in Composting

Raw Materials Input		% By Weight
Products:	Compost, including non-separable ballast materials (ferrous metal	30-60% 3-5%)
Solid residues:	e.g. glass ceramics, plastics, textiles, rubber etc. as far as separable	60-30%
Process losses:	Evaporated moisture, CO_2	10-30%

If the composting residues are disposed of to landfill - an expensive alternative is incineration - the volume reduction achieved through composting would be 50-70 per cent based on the in-place volume. Thus, there is still a substantial need for residue landfilling, if there is no additional materials recovery activity combined with the composting. However, residue landfill sites, if properly run, are more acceptable in terms of appearance and environmental impact, compared with normal landfill sites.

Besides household refuse there are other types of waste suitable for disposal or utilisation through composting:

- street sweepings, market wastes;
- sewage sludge;
- organic wastes from the food industry;
- wastes from the wood/paper industry (bark, saw dust, sludges);
- manure from industrial livestock production.

Most of these wastes should preferably be composted in mixtures with household refuse in which the moisture content should not exceed 45-60 per cent, depending on the system selected. In cases where one of the above mentioned wastes is the prevailing type, there may be special composting systems available, e.g. for sewage sludge.

A special advantage of composting which is also relevant, particularly with regard to sewage sludge disposal, is that it provides for reliable sanitisation if properly operated. Pathogenic organisms are destroyed at the temperatures of 60 to 75°C generated by biological decomposition, if kept at that level for a sufficient period of time (of the order of weeks in the case of windrow systems), and through antibiotic substances produced by fungi participating in the biological process.

The second step in investigating the feasibility of composting possibly even more important than the first, described above is to determine the local market potential for solid waste compost. In order to avoid disappointment it has to be made clear that solid waste compost is not a fertilizer to be compared, or to compete, with conventional industrial fertilizers. It is rather a soil conditioner which functions as a source of humus and nearly all the trace elements essential for vegetation, and then also contributes modestly, but not negligibly, to soil fertility.

An example of a typical compost composition is given in Table 2.

Some of the main areas of compost application in Europe are:

- landscaping, e.g. park and sport grounds development and maintenance, highway construction, etc;
- special cultures, e.g. vineyards, mushroom growing etc;
- horticulture, agriculture, especially on intensively used land;
- forestry, tree nurseries;
- waste land reclamation, e.g. landfills, erosion control, etc;
- other uses: e.g. as filter material for biological filters for odour control.

In all cases where foodstuff is produced on compost-treated land, special attention has to be paid to the heavy metal (e.g. Cd, Pb) content of the compost, the soil and the produce (Table 3).

Although most of the metal compounds contributed by compost are not available to or are not taken up by plants, a routine test programme should be set up in parallel to compost application (see Preliminary Guidelines for Solid Waste Compost Application, Germany 1977).

One should realise in this context that most of the conventional industrial fertilizers also contain heavy metals, some in fairly high concentrations.

The advisable application rates for compost vary over wide ranges: 30-120 tonnes per hectare are typical rates in agriculture and horticulture, depending on type of soil and crop. This rate would be applied annually if land use is extremely intensive, otherwise every second or third year.

Table 2. Composition of Compost from Solid Waste (based on tests carried out on 36 samples taken from the Duisberg (Dano) Plant, Federal Republic of Germany, 1970-73).

Criteria/Components		Average	Range
Particle size distribution, %:			
<3.15 mm		52	41 - 67
3.15- 7.1 mm		22	12 - 31
7.1 -16 mm		17	5 - 32
>16 mm		9	2 - 18
Dry matter	%	59.5	52.0 - 68.3
pH - Value (KCL)		7.9	7.5 - 8.6
Organic matter	%*	43.5	35.1 - 60.2
Degradable organic matter	%*	27.6	17.4 - 39.6
Total N	%*	0.65	0.22 - 1.2
Conductivity	%*	1.06	0.48 - 2.4
Total P as P_2O_5	%*	0.65	0.14 - 1.48
Total K as K_2O	%*	0.47	0.17 - 0.65
Total MgO	%*	0.61	0.35 - 1.08
Total $CaCO_3$	%*	3.98	2.85 - 5.46
Alkaline reacting constituents (CaO)	%*	7.0	3.8 - 13.2
Hot water soluble boron	ppm*	23.9	11.0 - 40.0
Active manganese	ppm*	66.0	39.9 - 98.0
Total copper	ppm*	200.0	100.0 - 326.0
Total zinc	ppm*	1,039.0	460.0 - 1,500.0
Total lead	ppm*	92.0	24.0 - 272.0
Total iron	ppm*	2.09	0.72 - 3.86
Total cadmium	ppm*	3.7	1.8 - 6.4

* = based on dry matter

Table 3. Information and Data on Tolerable Total Contents of Certain Elements in Cultivated Soils with Regard to the Health of Vegetation, Livestock and Man. (mg/kg air-dried soil) (proposal from Kloke - 1976)

Element		Total Content in mg/kg	
Name	Symbol	Normal Cultivated Soils	Tolerable in Soils (Proposal)
Arsenic	As	2 - 20	20
Beryllium	Be	1 - 5	10
Lead	Pb	0.1 - 20	100
Boron	B	5 - 30	25
Bromine	Br	1 - 10	10
Cadmium	Cd	0.1 - 1	5(a)
Chrome	Cr	10 - 50	100
Fluorine	F	50 - 200	200
Cobalt	Co	1 - 10	50
Copper	Cu	5 - 20	100(b)
Molybdenum	Mo	1 - 5	5
Nickel	Ni	10 - 50	50
Mercury	Hg	0.1 - 1	5(a)
Selenium	Se	0.1 - 5	10
Vanadium	V	10 - 100	50
Zinc	Zn	10 - 50	300(b)
Tin	Sn	1 - 20	50

a) Here, only a few analyses exist so that these figures must be treated with some reservation.

b) In hop and viniculture, where the application of Zn and Cu containing plant protective agents has already enriched the soil with these elements, the responsible agricultural research stations must check carefully the locational proportions.

The contents of elements tolerable in forestry are not yet known. Nevertheless, for forest vegetation, including berries and fungi found in wooded area, no recommended value above those in this table should be considered.

For vineyards and for other special forms of cultivation, up to 300 tonnes per hectare are used every third year, and in landscaping or for reclamation of derelict land, up to 1,500 tonnes per hectare or more may be applied.

Prices obtainable for solid waste compost are usually modest, in Germany presently 5-25 DM/t, which is small in comparison to the cost of composting solid wastes. It should be realised that producing and selling compost is part of an environmentally meaningful waste disposal system and not normally a commercial activity. So at the end of the second step of investigating the demand for compost, a well secured market based on low or even zero prices and proper compost usage should be valued more highly than maximum return potential under more risky conditions.

The third step to be taken, after investigations of the waste situation and the compost market have come to a sufficiently positive conclusion, would be an evaluation of the composting systems available. For purposes of general consideration, the large variety of systems and process design variations can be reduced to the basic choices in Fig. 1.

Composting in

windrows, heaps:	reactors, cells:
- with/without artificial aeration (forced draught or suction)	"static systems" (material stationary)
	or
- with/without mechanical turning of windrows	"dynamic systems" (material being constantly or intermittently turned or stirred)
- on an open or roofed site	
	Both types usually combined with subsequent treatment on windrows for final maturing and/or storage purposes.

Fig. 1. Composting Systems Available

One somewhat unique system which does not fit into the above categorisation may be mentioned: the Brikollare System by IWKA, Karlsruhe, Germany, in which the composting process takes place in piles of bricks ("mini-bales") made out of a mixture of refuse and sewage sludge using brick manufacturing equipment. Following a high temperature (~60°C) decomposition phase, the bricks dry out and stabilise within 2-4 weeks. The final product is prepared by grinding the bricks.

The first basic choice between a windrow or reactor system cannot be made without getting involved in the important subject of site selection.

Windrow systems require larger areas, i.e., towards the upper end of a range of 125-250 m^2 per tonne per day of refuse treated, which can be used as a rule of thumb. In addition, Windrow systems are somewhat more critical with regard to odour problems which generally occur, but can be more easily controlled in the case of reactor type systems. Thus, in an area sensitive to odours and if land acquisition costs are high, a reactor system might be preferred, whereas in a more remote location where land costs or land availability do not represent a limiting factor, one would select a simpler windrow system for economic reasons.

To comment briefly on the other choices:

Artificial aeration for windrow systems is usually recommended if the height of windrows is to exceed 2m.

Special mobile equipment is available for turning of windrows. Frequent turning (e.g. once a week for a month and monthly thereafter for about 2-3 months) can replace artificial aeration and also provides for thorough mixing of the composting material.

In regions with high precipitation rates it is advisable to use covered windrow sites to enable control of the moisture content of the compost material, thereby also avoiding problems associated with potentially severe pollution through run-off from windrow sites.

The choice between "static" and "dynamic" systems may seem difficult but is not really that important.

"Dynamic" systems (e.g. trommel reactors) provide for good mixing of the compost material but consume more energy. Some "static" systems like the "Blaubeurener Verfahren" (Germany) have become famous for the outstanding compost quality achieved.

A generally valid recommendation is to proceed towards composting with a simple and extremely flexible system, which can be further developed according to specific local requirements.

About the only critical point with regard to environmental impact of composting is the odour emissions typical of biological processes. By maintaining aerobic conditions, the odours can be kept to a minimum. If additional effort is required, simple but effective compost filters can be used to treat odorous process air e.g. the exhaust from reactors. This is forced through perforated pipes (about 80-100 cm diameter) covered with a layer of gravel and 1.0-1.2 m of compost which has to be kept moist. These odour filters have also been successfully used to treat odorous process air from other sources, e.g. sewage treatment plants and various industrial plants.

The cost of composting is obviously a more complex subject than in the case of baling or shredding.

As a basis for rough estimation, the following example may be sufficient. They are based on German conditions and reflect recent cost levels. Land cost is excluded in all cases.

The lowest costs are for simple windrow systems including at least mechanical equipment for shredding, tractors for turning of heaps and some subsequent mechanical treatment. The higher costs apply to more sophisticated reactor-type systems. Extremely complex systems, as built in Germany and Switzerland for instance, could (in a few cases) substantially exceed the ranges given in Tables 4 and 5.

Table 4. Investment Costs for Composting Plants

Annual Throughput (Tonnes)	Investment Cost	
	DM per tonne per day	Million DM
15,000 - 20,000	250 - 330	3.8 - 6.6
35,000 - 40,000	200 - 290	7.0 - 11.6
75,000 - 80,000	170 - 255	12.7 - 20.4
∿150,000	150 - 230	22.5 - 34.5

In general, the mechanical plus electrical equipment, inclusive of assembly, form 55-70 per cent of the investment cost, and construction, 30-45 percent, including site development etc.

The total cost per tonne of waste composted is given in Table 5 based on one-shift operation. This includes all operating effort, capital depreciation, etc. Very roughly, about one half of the cost would be for operation and half for capital charges etc.

Table 5. Total Cost for Composting and Manning Requirements

Annual Throughput	Total Cost DM per tonne of waste	Personnel Required
15,000 - 20,000	55 - 85	6 - 9
35,000 - 40,000	45 - 70	9 - 13
75,000 - 80,000	35 - 60	13 - 19
∿150,000	30 - 50	17 - 25

Of the personnel required, about one third would have to be skilled workers, familiar with mechanical and electrical installations and at least one staff member should be experienced in agriculture to supervise and promote compost utilisation.

It is probably true to say that, in practically all countries, solid waste composting still lies far short of its potential rate of application as a useful means of disposing of waste, recovering resources, and contributing to the conservation of soil fertility, which may become increasingly important as costs of industrial fertilizers rise.

A particularly interesting area for future development seems to lie in combining composting with mechanical sorting systems for materials recovery and waste-derived fuel production, with the sorted moist, organic fraction being suitable as a raw material for composting. Demonstration projects of this type are under way in a number of Western countries and Japan.

THERMAL TREATMENT OF HOUSEHOLD WASTES

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INTRODUCTION

Wastes, the metabolic products of human society, arise continuously and burden the environment in so far as they are not handled in a controlled manner and transformed into residues capable of being harmlessly disposed of. Incineration has proved to be a particularly effective method of converting wastes into harmless and hygienically unobjectional products. The heat generated at the same time represents a source of energy which to varying degrees, may be used.

The idea of incinerating refuse was first realised about 100 years ago in England in 1876. This new method of handling also began to be utilised shortly after in the USA in 1881. During this period, refuse incineration was primarily aimed at hygienically disposing of potential substrates for bacteria.

In Germany, the first large refuse incineration plant was erected in 1893 in Hamburg as a measure against epidemics. Further plants followed. A large proportion of these plants soon had to close down again on account of various defects in their construction and insufficient profitability, upon which many had set great hopes.

The development of living standards after the Second World War brought a steady increase in the generation of refuse with characteristics more suited to incineration. In view of new environmental protection laws, many cities therefore decided to solve their waste disposal problems by refuse incineration. In the Federal Republic of Germany, some 17.4 million inhabitants, corresponding to 28.3 per cent of total population, will be served by 44 refuse incineration plants by 1980.

It is estimated that by 1990, about 20 - 30 new incineration plants will be erected, predominantly in urban areas. In this situation, the needs of about 32 - 34 per cent of the population could be catered for by refuse incineration plants.

The technical and economic details of refuse incineration are examined in more detail in the following sections. However, beforehand, the more recent developments in the field of thermal treatment of waste are discussed in a separate section, and which has recently gained a particular significance from the point of view of energy and resource recovery.

NEW PROCESSES OF THERMAL WASTE TREATMENT

Besides refuse incineration, considerable activity has been taking place for some time now in the field of thermal waste treatment in respect of processes for the thermal reduction of wastes, because those wastes which can be incinerated, may also, with a few exceptions, be decomposed thermally. The critically important characteristics in this regard are primarily material type, particle size, moisture content and calorific value.

Gasification and De-gasification of Household Wastes

With thermal decomposition, the organic components of the wastes are broken down into condensable liquid components (e.g. tars, heavy oil, light oil, alcohol), into non-condensable liquid components (vapours and gases such as H_2, CH_4, CO, etc.), and a solid residue which can contain a relatively large amount of carbon.

De-gasification (pyrolysis) is a process in which the organic material is broken down at relatively high temperatures into molecules with a lower molecular weight. The process takes place in the absence of air. With pyrolytic conversion, there emerges a wide range of products with varying frequency. Their quantitative and qualitative composition is determined essentially by 3 factors, namely, by the composition of the input material, by the heating conditions and by the residence time during the pyrolysis process.

Gasification describes the conversion processes by which solid fuels are converted into flammable gas through partial oxidation with free or combined oxygen. Here, it is important that the oxygen does not derive from the fuel. It can in elementary form be introduced with air. One then obtains a lean gas or air gas. In other processes, it is introduced in concentrated or pure form. If steam is employed as the oxidising agent, then one obtains water gas. A further oxygen carrier is carbon monoxide as a component of the flue gases. With proper partial oxidisation of the fuel, only carbon monoxide and hydrogen are formed. In practice, however, there always appear certain quantities of solid carbon, methane and other hydro-carbon compounds, and carbon dioxide. This demonstrates that other processes occur besides partial oxidation, namely pyrolysis, hydrogenation, and oxidation.

The process possibilities for the thermal decomposition of wastes are of necessity considerably more numerous than for example with coal and wood, on account of the inhomogeneous nature of the initial material. Various possibilities exist in respect of:

- the design of the reaction chamber (open - closed)
- the arrangement of the chamber (vertical - horizontal)
- the running of the process (in a static bed - in a gas stream)
- the heating of the reaction chamber (external - internal)
- the process temperature (500° C up to 1500° C)
- the temperature distribution in the reaction chamber and
- the reaction time (residence time of the waste in the various temperature zones of the chamber).

From the thermal decomposition of waste, the following end products can arise:

- fuels (or raw materials) in the form of tars, oils, flammable gases;
- condensed water with dissolved contaminants contained therein;
- residues, consisting of refuse char which cannot be pyrolysed any further, metals, glass, sand and similar materials.

The gas, oil and tar can be sent for fractional separation through tar and oil separators as well as through gas washing systems. For this purpose, conventional equipment associated with incineration can be utilised. The recovered gas must be cleaned to remove harmful components such as dust, SO_2, H_2S, NH_3, HCl etc. Interim storage in conventional gas containers is possible.

After removal of tars and cleaning, the oil product can either be employed as a fuel in the system or be recovered as a raw material. To the extent that the wastes have not already been previously processed, the metals and glass can be recovered from the solid residues.

Solid pyrolysis residue (pyrolysis char), because of its relatively high carbon content, can be further utilised for a variety of purposes (e.g. combustion, gasification, manufacture of activated carbon).

Fuel from Refuse

In "traditional" waste incineration of the type used in Europe for a long time, the refuse, with the exception of bulky refuse, is burned in an unpulverised form. Separation of usable materials prior to incineration does not as a rule occur. Scrap is recovered from the ash and the ash itself can be utilised in road construction.

If the wastes are pulverised in such a way that, after simple classification e.g. air classification, one obtains a light fraction with a considerably higher calorific value than that of the original refuse (ca. 12,000 to 16,000 kJ/kg) then this fuel can be burned in power plants together with primary fuels. This type of processing can be combined with material recovery either prior to incineration and/or after incineration, from the ash. This process was tested in a demonstration plant in the USA from 1972 to 1976 in 2 tangentially-fired steam boilers (throughput ca. 51 tonnes of coal per hour); some 10 per cent of the total heat output (corresponding to 11.3 tonnes of refuse per hour) was produced by the combustion of refuse. In a number of test, this percentage was increased to 25 per cent. The combustion temperature amounted to 1300^{o} C to 1400^{o} C, and the residence time, 1 - 2 seconds.

There are also processes under development in which the wastes are processed in several steps, with both pulverisation and classification. The aim of this type of processing is the manufacture of a higher quality fuel, which can be stored, transported and sold to various consumers. Comprehensive recovery of materials is also included in the processing.

All of these new thermal processes, both degasification and gasification processes as well as the recovery of fuel from refuse, are still under development. As far as the Federal Republic of Germany is concerned, their introduction on a large scale is not expected before 1980/81. For this reason, verifiable data on the construction and operation of such plants cannot be given. The following description therefore relates only to refuse incineration, which is the most developed and, at the present time, exclusively employed process for thermal treatment of waste.

THE BASICS OF REFUSE INCINERATION

Incineration serves first of all as a method of treating wastes prior to disposal. Incineration in modern refuse incineration plants is an established and proven method of rapidly rendering wastes inert in a controlled manner.

It also affords the possibility of using the heat generated as a welcome spin-off. Besides which, the use of heat from the incineration of household refuse is becoming of increasing interest economically, because the municipal refuse in many areas already attains a calorific value which corresponds to that of brown coal. This amounts currently to 6,300 to 10,500 kJ/kg. However, whether it will increase to 12,500 kJ/kg as is frequently predicted, is uncertain. Nevertheless, refuse incineration plants currently being planned or under construction are already being designed for calorific values of this level.

Waste Types and Residues

Depending on the type of plant, the types of waste given in Table 1 are burned in municipal refuse incineration plants.

Table 1. Types of Waste Burned in Municipal Refuse Incineration Plants

Waste Type	Calorific Value	
	(kJ/kg)	(kcal/kg)
Household Refuse	6,300 - 10,500	1,500 - 2,500
Bulky Refuse	10,500 - 16,800	2,500 - 4,000
Commercial & Industrial refuse (similar to household)	7,600 - 12,600	1,800 - 3,000
Used oil	33,600 - 42,000	8,000 - 10,000
Sewage Sludge (75% water content)	1,200	290
Residues from composting	6,300 - 10,500	1,500 - 2,500

The solid residues from incineration which arise as ash and fly-ash, occur.at the points in Table 2.

Table 2. Solid Residue from Incineration

Residue	% by weight of refuse throughput, dry	Unit Weight
Fall-through from grate	1 - 2	2,000 - 3,000 kg/m^3
Grate discard	20 - 35	1,200 - 2,000 kg/m^3
Fly-ash from the boiler flues) Fly-ash from glue gas cleaning)	3 - 6	600 - 1,000 kg/m^3
Dilute sludges from flue gas scrubbing (95% water content)	0.05 - 0.5	-

Volume reduction amounts to approximately 85 - 90 per cent.

The technical and economic conditions for separating ferrous scrap from incineration residues and for recovering the slag are found only in the larger plants. The separation of ferrous scrap relies primarily on electro-magnetic methods and, in this regard, over-band magnets have proved to be better than drum magnets.

The ferrous scrap is accepted by the scrap dealer either in loose or compacted form and delivered to the steel works. The value of the scrap is subject particularly to seasonal and regional fluctuations. The separation of non-ferrous metal scrap from incinerator residues is still at the development stage. This valuable secondary raw material is currently land-filled together with the non-recoverable residues.

The slag arising in refuse incineration plants is tipped in the majority of cases. It is used to some extent for filling sand and gravel pits, where possible interference with ground water by the soluble salts in the slag and ashes must be taken into account. A further possibility for application is use of the slag in road construction is being investigated.

The fly-ash from gas cleaning, which makes up about 10 - 15 per cent of the residues, contributes to a considerable extent to the leaching potential of the residues. It would therefore appear sensible not to mix these up with the incinerator residues, as is customary, but to treat and recover these separately. The tipping of slag free of fly-ash could therefore, under certain circumstances, be carried out without any problem.

Processing of slag and ashes via high temperature processes into building materials such as sintered pumice is possible in principle, but is not currently carried out because of the associated costs. Consideration of ways in which the materials contained in fly-ash separated by the electrostatic filters might be used has not yet reached any firm conclusions.

Heat Recovery

The multitude of possible circuits and combinations for using energy in waste incineration plants can be broken down basically into 5 types.

Type	Description
A	Refuse-district heating plant.
B	Refuse-district heating plant with power production for in-plant use.
C	Refuse-condensing power plant.
D	Refuse-power plant with district heating capacity.
E	Combined refuse and fossil fuel power plant with district heating capacity.

Type A - Refuse-district heating plant.

Steam or hot water is producted at low pressure and fed into a district heating network or into the steam network of an industrial operation. As the heat demand of a district heating system is characterised by small daily fluctuations, but substantial seasonal fluctuations, refuse-fired heating plants are mostly operated in parallel with conventional heating plant. Usually the base load is supplied by the refuse-fired part of the heating plant.

Type B - Refuse-district heating plant with power production for own use.

Prior to feeding into a district heating plant or a heat exchanger, the steam is passed through a back-pressure turbine to produce electrical energy which is at least sufficient to cover the needs of the plant.

Type C - Refuse-condensing power plant.

In this type of plant, the high pressure steam produced is conveyed to condensing turbines with a high thermodynamic efficiency. The electrical energy produced is fed into the public grid.

Type D - Refuse-power plant with district heating capacity.

The plant is built in the same way as type C, but bleeder condensing turbines are employed. The bleeder condensing turbines allow seasonal changes in demand for heat of a district heating network to be extensively matched to periods of high demand for power; this enables an economically optimal operation to be achieved.

Type E - Combined refuse and fossil fuel power plant with district heating capacity.

The construction resembles type D, but the refuse incineration is an integrated part of a coal, oil or gas-fired power plant boiler. This type of construction has hitherto only been used in large power plants.

Standard Data for the Recovery of Heat and Power from Refuse Incineration

The residual heat extracted via a steam boiler can amount to up to 80 per cent of the total energy brought into the plant in the refuse and the combustion air, which, however, would place very high demands on the quality of the furnace-boiler unit as well as its operation.

In general, steam production efficiencies lie at about 70 per cent or even lower in correspondingly less expensive plants. In Tables 3 and 4, the results of energy recovery of various refuse incineration plants are given.

With respect to the values for the plants at Rennes, KEZO-Hinwill and Paris-Ivry, it should be noted that the figures are quoted from acceptance tests. In practice, the operating efficiencies might be somewhat lower.

Table 3. Incineration Capacity, Steam and Power Production, and Efficiencies of Various Waste Incineration Plants

Plant	Type	Capacity t refuse/ day	Average CV of refuse kJ/kg (kcal/kg)	Steam Production t/t refuse	Steam Production efficiency % (1)	Power Production kWh/t refuse	Power Production efficiency % (2)
Rennes	A	120	7,790 (1,860)	2.2	75	-	-
Vienna-Spittelau	B	720	8,500 (2,030)	2.2	69	-	-
KEZO-Hinwill	C	120	8,160 (1,950)	2.4	77	365	16
Hamburg-Stellinger Moor	C	912	7,960 (1,900)	1.7	62	303	14
Paris-Ivry	D	2,400	8,250 (1,970)	2.2	74	-	-
Munich-North Block II	E	960	7,120 (1,700)	1.7	63	527	27

(1) Steam production efficiency: heat content of the steam raised, as a percentage of the calorific value of the refuse input.

(2) Power production efficiency: net delivery as electrical energy, as a percentage of the calorific value of the refuse input.

On the basis of values from the KEZO-Hinwill and Hamburg-Stellinger Moor plants, 2 modern plants, typical values for the recovery of energy can be calculated and are presented in Table 4.

Table 4. Energy Recovery Values

Calorific value of the refuse	7,960 - 8,160 kJ/kg (1,900 - 1,950) kcal/kg)
Steam production per t of refuse	1.9 - 2.4 t
Power Production per t of refuse	300 - 365 kWh
Refuse required in kg per kWh	2.7 - 3.3
Energy required from the refuse in kJ(kcal) per kWh	22,020 - 26,250 (5,260 - 6,270)

From the values in tables 3 and 4, it can be seen that to produce 1kWh of power, about 2.7 - 3.3 kg of household refuse with a calorific value of around 7,960 kJ/kg (1,900 kcal/kg) must be incinerated.

Environmental Loads

A substantial burden for the environment which can result from the incineration of refuse, is that created by the dust and noxious gases contained in the flue gas.

Table 5 gives an overview fo the maximum concentrations of pollutants which have been determined by numerous emission measurements at large municipal and industrial incineration plants.

Table 5. Maximum Emitted Pollutants

Solids Ash and dust	2,000 to 15,000 (mg/m^3)
Noxious gases	
Cl-	< 1,500 (mg/m^3)
F-	< 20 (mg/m^3)
CO	< 5,000 (mg/m^3)
SO_2	< 1,000 (mg/m^3)
NO	< 500 (mg/m^3)
NO_2	< 50 (mg/m^3)

The type and quantity of the pollutants contained in the flue gas depends primarily on the composition of the wastes, the type of incineration system, the controlling of the flue gas in the furnace, and the incineration temperature. Separate gas cleaning processes are normally required.

The removal of dust is possible with cyclones, bag filters, electrostatic cleaning systems and wet scrubbers. Cyclones do not achieve a sufficient removal efficiency, particularly with fine particles. Bag filters demand extensive cooling of the flue gases and are very expensive. Wet scrubbers afford the possibility of simultaneously eliminating the noxious gases, but they have not been applied because of the large unit throughputs of water and the high losses in pressure. Moreover, the particulate matter must then be separated from the scrubber effluent in a further process step, and the resulting sludges de-watered. A further problem is caused by the heavy metals found in elevated concentrations in particulate form, which would go into solution with wet scrubbing.

In the Federal Republic of Germany, electrostatic filters have found common use on account of the high removal efficiency required. A total of 37 out of 41 plants are fitted with these. Removal efficiencies from 98 to over 99 per cent are being achieved. In newly-erected plants in which the elimination of toxic gases becomes necessary, the separation of dry removal of dust by means of electrostatic filters and wet removal of noxious gases will be unavoidable.

Various types of scrubber have proved reliable for the absorption of the noxious gases HCl and HF from the flue gases. All of these make use of the solubility in water of the gases to be removed, but, in addition, the removal of SO_2 is necessary which requires the use of alkaline absorption agents on account of its poor solubility in water.

Dry removal processes which are based on the absorption of the toxic gases by means of suitable absorption agents (e.g. lime CaO) with subsequent dust removal, do not achieve the necessary removal efficiency at acceptable costs. From the point of view of water management, its introduction would certainly be welcomed.

The clarified water arising from the gas scrubbers must undergo further treatment before being discharged. Usually, neutralisation with lime milk $Ca(OH)_2$ or caustic soda NaOH is carried out and the solids separated in settling basins. Depending on the neutralising agent, the salts $CaCl_2$ and CaF_2 or NaCl and NaF result.

If the condition of the receiving water does not permit discharge of saline effluent, then these must be treated. This is carried out by single or multiple stage evaporation for which the usable heat from refuse incineration can be applied. This type of facility is either planned for or already under construction in several refuse incineration plants.

Scrubber effluent can also present a thermal burden for the receiving water, as it leaves the scrubber at a temperature of ca.330^{o} K.

If need be, it must be cooled in heat exchangers before discharge.

Effluent from the wet treatment of slag only arises in small quantities. As a rule, it does not present a problem. It is weakly alkaline so that frequently it can be employed for neutralisation. Nevertheless, it should be passed through a settling basin to remove the solids prior to discharge to the receiving waters.

Pollution of the land can result from the sludge and solid residues arising. Among the former are included the dilute sludges from the sedimentation basins for the slag quenching effluent as well as the effluent from the scrubbers. The latter include the slags and fly-ash. Because of the soluble components contained in these, the same conditions are as a rule applied in their tipping as with landfilling of crude refuse.

Investigations have shown that fly-ash-free slags are only slightly leachable. Therefore in relative terms, they can be harmlessly tipped. The position is different in the case of tipping of fly-ash, from which harmful substances can be extensively leached. In quantitative terms, the most significant components of the leachates would be sodium, calcium, sulphate and chloride. In addition, volatile heavy metals such as zinc, lead, cadmium and fluoride, are also leached out. The heavy metals get into the fly-ash because they are not combined in the slags on account of their low boiling point, but leave the combustion chamber in the form of a gas or as an aerosol.

From this, the conclusion has been reached that fly-ash should no longer be tipped together with slag, as has been the case until now, but to reduce the high water solubility of some of the components through suitable treatment (e.g. compaction of the fly-ash).

A completely satisfactory solution for the final treatment of the dilute sludges from the scrubber effluent has also not been found until now. If they are added to the refuse slag together with the ash from the electrostatic filters, there exists the danger of washing out by the precipitated water. Its discharge to sewer might likewise not be really acceptable.

Noise emissions emanate predominantly from rapidly running process machinery (compressors for the combustion air, exhaust gas ventilators) and, where used, from size reduction equipment. They may be controlled by encapsulating the sources of the noise or by housing in a closed building.

Plant Capacities

For economic and ecological reasons, the main emphasis of refuse incineration lies in the area of large scale plants for urban regions. Most of the plants have a throughput of more than 10 tonnes per hour corresponding to at least 100,000 inhabitants served. In the Federal Republic of Germany, about 76 per cent of the population in urban areas of this size are served by refuse incinerators. Almost two-thirds of the large scale plants presently in operation have throughputs of more than 30 tonnes per hour with at least 300,000 inhabitants served. Following the trend of recent years, the future development of refuse incineration will also be concentrated on plant capacities of at least 10 tonnes per hour.

DESCRIPTION OF SELECTED PLANTS

The majority of refuse incineration plants in the Federal Repulic of Germany were constructed after 1965. In the first instance, the plants were characterised by the following features:

- Utilisation of new grate constructions developed in part for the incineration of waste, such as for example the roller grate of the Dusseldorf system, or the reciprocating grate later developed for refuse incineration in the Martin system.

- Intensification of heat recovery at the beginning of the period, frequently with over emphasis of the thermodynamic aspects, with negative consequences for availability (corrosion of the heat surfaces) towards the end of the period under consideration with clearly reduced claims for heat recovery.

- Extension of automation from the grate and de-slagging to cleaning of the heating surfaces as well as the complete air-flue gas-train.

- Accommodation of the substantially increased calorific value of refuse of the intervening period, by reducing construction costs for ignition and support firing, and preheating of the combustion air.

- Improvement of environmental controls, in particular through improvements in filter efficiency.

- Increasing utilisation of radiant boilers built directly onto the grates.

- Increased centralisation of operation, monitoring and control.

- Development of ancillary arrangements such as bulky refuse reduction, slag and scrap processing.

A typical design example is the Dusseldorf refuse incineration plant, which is described below:

Design Example - The Dusseldorf Incinerator

The mode of operation of a refuse incineration plant with heat recovery is the same for all plants with respect to the essential processes, and is explained using the example of the Dusseldorf plant.

The refuse is conveyed with grab cranes into the charging hopper of the incinerator. It reaches the grate system via the feed mechanism where it is incinerated with air fed from the bunker. Combustion proceeds at a temperature range of 900-1000° C. Cooling of the hot combustion gases takes place through heat exchange for the recovery of hot air, hot water or steam. Electrical energy is recovered with steam turbines while hot water or steam finds application in district heating. The cooled combustion gases have any particulate matter removed in filters and are discharged to atmosphere via the stack. The slag is delivered via the slag quenching tank (Fig. 1).

Commencement of operation was in 1965 and it is operated by the City of Dusseldorf.

Plant technical data (first construction stage)

Mode of operation	3 shifts per calendar day
Installed capacity	4 x 240 tonnes per day
Number of incinerator units	4
Combustion system	Roller grate, System Dusseldorf
Form of heat recovery	Steam production
Form of flue gas cleaning	Electrostatic filters
Bulk refuse reduction	Available
Drying and addition of sewage sludge	Not available
Processing of slag and scrap	Available
Type of waste incinerated	Household refuse and similar industrial and commercial wastes
Calorific value - range	1,000 to 3,000 kcal/kg
Flue gas volumes	50,000 Nm^3/h and unit
Installed boiler capacity	4 x 20 tonnes/h, 1 x 30 tonnes/h
Installed turbine capacity	Not envisaged, as steam is delivered to an existing power station
Live steam condition at boiler outlet	105 excess atmospheric pressure, 500° C
Feed water temperature	150° C
Ignition and support firing capacity	2.5 Gcal/h
Usable bunker volume	10,000 m^3
Interior space of the total plant including ancillary equipment	130,000 m^3
Built on area of the total plant including ancilary equipment	4,840 m^2

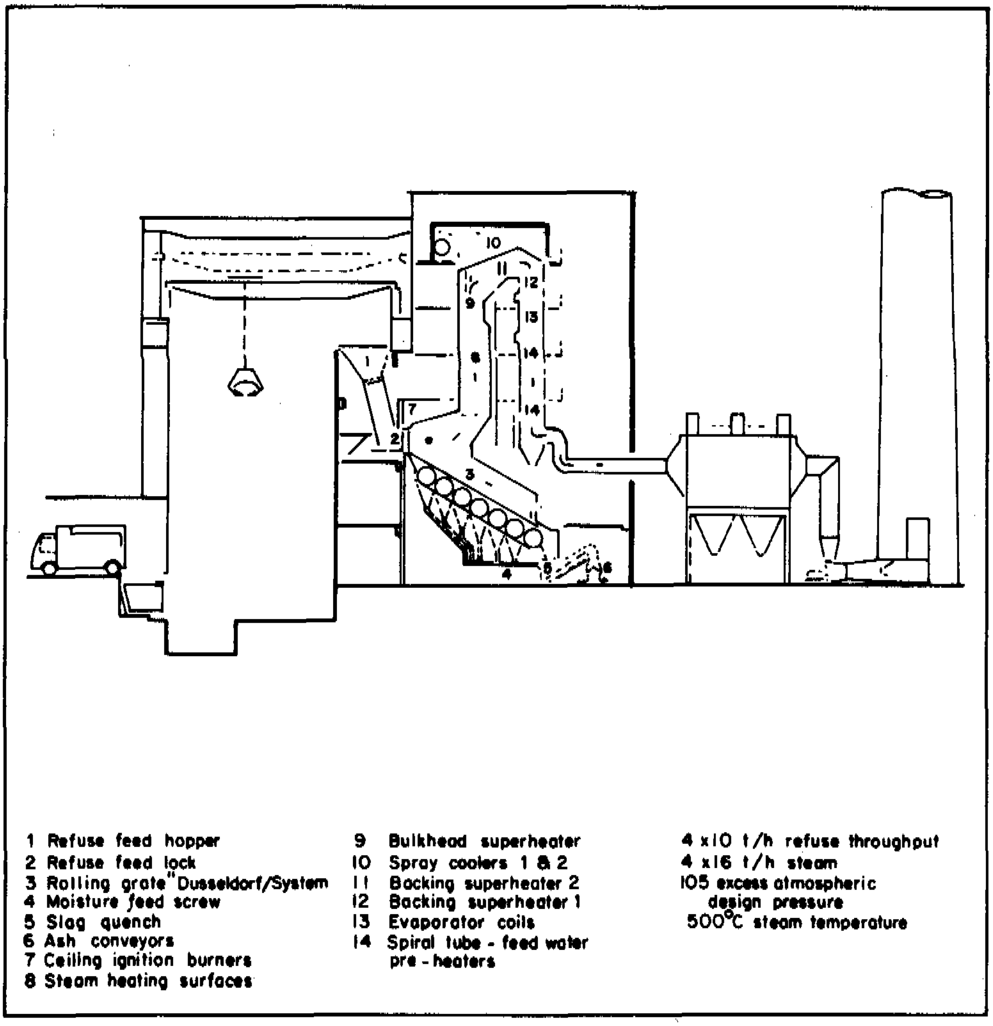


Fig. 1. The Dusseldorf Incinerator

In contrast, the plants planned, built and operated since 1972 have the following features:

- The utilisation of flue gas scrubbers for the reduction of gaseous emissions, particularly in respect of HCl and HF.
- More concentrated exploitation of the residual heat while avoiding methods which create corrosion problems in respect of the flue gas.
- Adapting the combustion chamber arrangement to the substantially increased calorific values through air-cooled side walls, and intensifying the admixing of secondary and, if need be, tertiary air to avoid caking of the slags.
- Extensive automation and centralisation of monitoring of the peripheral equipment, heat utilisation etc.
- Extension of environmental control measures to the effluent and noise sectors.

A typical example of application is the refuse incineration plant at Krefeld, which is described below:

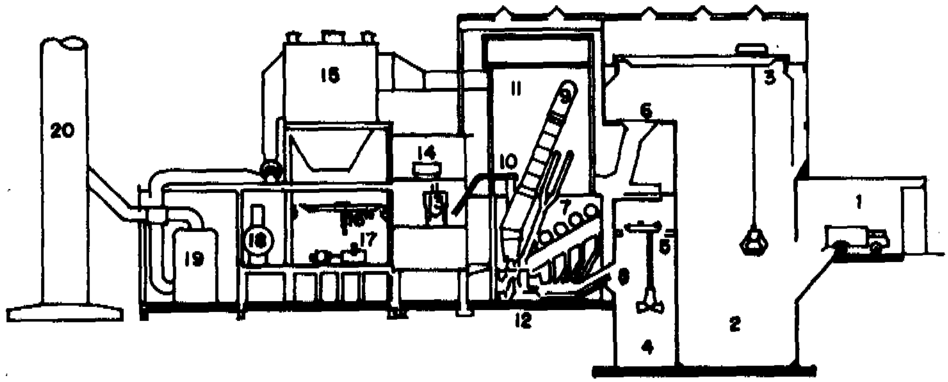
Design Example - The Krefeld Incinerator

The refuse arrives via the weighbridge, where the weight and origin are recorded, at the tipping bays or the bulky refuse shear of the refuse bunker, from where it is brought into the bunker. From here, the refuse is delivered by remote controlled cranes to the feed chutes of the individual incineration furnaces, where it is burned on roller grates (Fig. 2).

The sludge arising at the sewage treatment plant, with a water content of ca. 94 - 95 per cent, is delivered to a storage bunker at the refuse-sewage sludge incineration plant, and is then centrifuged to the point where the water content is reduced to ca. 74 - 76 per cent. This thickened sludge is then dried and ground in impact mills to which hot flue gases are admitted. The blowing in of the dust and the exhaust vapours takes place directly over the refuse combustion chamber. Here, the dust then burns in free suspension.

Used oil is fired through power burners after suitable processing. The ash arising from the combustion of all waste materials, including the fly-ash, is cooled in slag quenchers and conveyed to the ash bunker. From this bunker, the ash is loaded into trucks with a remote controlled crane and then transported away.

To exploit the heat release by incineration, the furnaces are connected to down-stream steam generators. The resulting superheated steam is converted into electrical energy in back pressure turbines.



1 Unloading bay
2 Refuse bunker
3 Refuse crane
4 Ash bunker
5 Ash crane
6 Refuse feed hopper
7 Roller grate "Dusseldrop System"
8 Slag quench
9 Flue gas recirculating pipe
10 Sludge feed pipe
11 Steam generator
12 Impact mill
13 Sludge bunker
14 Centrifuges
15 Electrostatic filter
16 Machine-house crane
17 Turbo generator
18 Feed water container
19 Gas scrubber
20 Stack

Fig. 2. The Krefeld Incinerator

This energy is sufficient for the needs of the plant including the sewage treatment plant. The residual steam behind the turbines is used for district heating.

Before the flue gases are released to the atmosphere via the stack, the particulate matter in the gases is reduced in a first cleaning stage to a residual content of about 2 per cent, and in a second cleaning stage, the noxious gases such as hydrogen chloride, sulphur dioxide and hydrogen fluoride are for the most part scrubbed out.

Commencement of operation was in 1975 and it is operated by the City of Krefeld.

Plant technical data

Mode of operation	3 shifts per calendar day
Installed capacity	2 x 240 tonnes per day
Number of incineration units	2
Incineration System	Roller grate, Dusseldorf System
Form of heat recovery	Steam production
Form of flue gas cleaning	Electrostatic filters gas scrubbers
Bulky refuse reduction	Available
Sewage sludge admixing and drying	Available
Slag and scrap processing	Not envisaged
Types of waste incinerated	Household refuse and similar industrial and commercial wastes
Calorific value - range	900 - 2,500 kcal/kg
Flue gas volumes at boiler end	85,500 Nm^3 per hour
Installed boiler capacity	2 x 42 tonnes per hour
Installed turbine capacity	2 x 1.4 MW.
Live steam condition at boiler exit	375° C - 23 excess atmospheric pressure
Feed water temperature	140° C
Ignition and support firing capacity	3.0 Gcal/hour
Usable bunker volume	6,000 m^3
Interior space of the total plant including ancillary plant	77,840 m^3
Built over area of the total plant including ancillary plant	3,520 m^2

COSTS OF REFUSE INCINERATION

Investment and operating costs are the decisive factors for the economics of a refuse incineration plant. Their size is dependent on a number of influencing parameters, which can be subject to large variations from plant to plant. Transferable, generally valid values can therefore not be established without qualification. The figures given below are only approximate.

Investment Costs

Decisive factors for the investment cost of a refuse incineration plant are:

- installed capacity in tonnes per hour,
- type and extent of heat recovery,
- type and extent of flue gas cleaning,
- type and extent of ancillary plant for slag processing or sludge drying and incineration,
- type and extent of conveyance/cooling of surplus energy,
- number of installed units and the sub-division of the total installed capacity,
- extent of pre-investment for further extension.

In addition to these prime factors, there are still a number of subsidiary factors relevant to the level of investment, which as a rule are less significant. These include:

- site acquisition costs,
- site services,
- transport access to the site,
- condition of the site.

In Table 6, the investment costs (1976 price level) for 2 types of plant are given.

Type A

Theoretical capacity: 4 x 10 t/h with district heating production, power production, slag processing and scrap recovery.

Type B

Theoretical capacity: 2 x 10 t/h with district heating production and sewage sludge incineration (maximum 17.5 per cent of the total throughput).

Operating costs

The most important influencing factors on the level of operating cost of refuse incineration are:

- capital costs, i.e. depreciation and debt charges of the capital employed,
- expenditure for repairs, maintenance etc.,
- manpower costs,

Table 6. Investment Costs for Incinerator Plants (2 Types)

	Type A	Type B
Site acquisition	540,000	430,000
Civil works	17,200,000	11,900,000
Mechanical plant	40,000,000	25,600,000
(of which, for the flue gas system and gas cleaning)	(7,600,000)	(5,100,000)
Electrical plant	7,000,000	5,200,000
Plant investment and site acquisition	63,740,000	43,130,000
Other investment costs (e.g. fees, charges, construction financing)	12,800,000	9,000,000
Total Investment (DM)	76,540,000	52,000,000

- credits from the sale of power and heat, or other residual products.

Other remaining factors such as: water and power cost; chemicals; transport and tipping of residues are relatively insignificant.

The incineration of wastes requires large investments to be made. In this way, the capital costs can account for up to 80 per cent of the costs of incineration. The type of financing and method of depreciation, which substantially influence the level of these capital costs, are therefore as a rule far more decisive for the costs of incineration than manpower, maintenance or material costs.

The following bases of calculation are customary:

Debt charges on capital:

No generally valid statement possible.

Depreciation period:

25 years for the total plant <u>or</u> 40 years for the civil works; 15 years for plant components susceptible to rapid wear; 20 - 25 years for plant components with normal rates of wear.

Maintenance and repair:

2 per cent of total investment per annum or 1 per cent of total investment in civil works per annum; 1.5 - 2 per cent of the investment in electrical plant per annum; 3 - 4 per cent of the investment in mechanical plant per annum.

Manpower costs:

Average value: DM 40,000 per man and year (1976 prices). Personnel requirements according to number and size of incineration units, the operating mode and the extent of ancillary equipment, ca. 35 - 65 men.

In Table 7, examples of the annual operating costs are given for the same types of plants as in Table 6 (1976 prices).

Table 7. Annual Operating Costs for Incinerator Plants (2 Types)

	Type A	Type B
Capital charges	8,900,000	4,900,000
Maintenance & repair	1,700,000	900,000
Personnel costs (number)	2,400,000 (60 men)	1,800,000 (45 men)
Tax, insurance, administration	1,460,000	840,000
Operating materials (water, chemicals, additional fuels)	1,300,000	3,700,000 (1)
Revenue (Power, district heat, slag, scrap)	7,700,000	6,450,000 (2)
Total Costs (DM per annum)	8,060,000	5,690,000
Total Unit Costs (DM/tonne)	32.80	56.20

(1) including sewage sludge conditioning.
(2) including sewage sludge acceptance.

OUTLOOK

The development of waste incineration technology has received new impetus, particularly in recent years. In respect of the main objectives of:

- improvement and simplification of incineration techniques,
- reduction of emissions of noxious substances,
- reduction of investment and operating costs.

Further development is needed in particular in the following areas:

- more extensive automation of refuse incineration,
- optimisation of existing, and introduction of new flue gas cleaning systems for removing noxious gases,
- more extensive exploitation of the possibilities for heat recovery, e.g. incorporation in supra-regional, co-ordinated district heating systems and sewage sludge treatment,
- attaching the largest possible catchment areas to central incineration plants.

In these respects, refuse incineration can also be viewed in future as a suitable process for waste removal in urban areas.

In evaluating the newly developed thermal processes such as de-gasification, gasification and refuse derived fuel, the criteria of environmental impact, technical reliability and economic viability are of essential importance. There are, however, still problems in evaluating against these criteria, as only test, pilot or demonstration plants exist until now. The first conclusive results from the practical testing of developments on a large scale can be expected in 1980/81.

REFERENCES

Barniske, L., (1977) Thermal Processes for Waste Disposal, der Landkreis, pages 353 - 357.

Barniske, L and Voskühler, H, (1978) Status of Refuse Incineration in the Federal Republic of Germany, Müll und Abfall, pages 157 - 166.

Fichtel, K., (1977) Thermal Processes - Energy Recovery from Waste Materials in Abfallwirtschaft und Recycling, published by E. Keller, Essen, pages 200 - 212.

Goepfert und Reimer, (1977) Investigation of the Costs Structure of Various Processes for Disposing of Urban Wastes, carried out under contract from the Federal Environment Agency, Berlin.

Nels, Ch., (1977) Possibilities for Thermal Waste Treatment with Respect to Energy and Raw Material Recovery, paper given at Envitec Düsseldorf, unpublished manuscript.

Nels, Ch., (1978) Thermal Waste Treatment and Environmental Problems - Müll und Abfall (7/78), pages 214 - 219.

Reimer, H., Operating Costs and Economics of Refuse Incineration Plants - Müll und Abfallbeseitigung, published by Straub, Hösel, Schenkel, Volume 3, Section 7800.

HANDLING, TREATMENT AND DISPOSAL OF HAZARDOUS WASTES

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INTRODUCTION

One of the serious drawbacks of the technological era is the steadily increasing amount of hazardous wastes being produced daily by industry, agriculture, government, hospitals and laboratories. To protect human health and the natural environment it is imperative that safe handling and disposal techniques for these wastes be used. Increasingly, environmental managers at all levels of government will be required to make decisions on how to cope with hazardous wastes.

Hazardous wastes comprise only a small fraction of all wastes generated by an industrial society. The primary source of such wastes is the industrial sector. But even of the industrial wastes proper, only a fraction can be considered hazardous and, therefore, must be handled and disposed of with special precautions. The environmental impact of hazardous wastes, however, may be out of all proportion to the amounts because of the threats of severe health and environmental effects, both chronic and acute.

A brief and simple definition of a hazardous waste would encompass those wastes which cannot or should not be handled or disposed of in the same manner as the community's normal residential solid waste load. The determination of whether a waste is hazardous would stem from a judgement that a significant potential exists for causing adverse public health or environmental impacts if the waste is handled, stored, transported, treated or disposed of in the manner generally accepted for ordinary solid wastes.

General categories of hazardous waste are toxic, chemical, flammable, radioactive, explosive, and biological. They are mostly liquids but also occur as gases, solids, and sludges. Hazardous waste includes toxic chemicals, pesticides, acids, caustics, flammables, explosives, biological and radiological residuals.

Only in recent years have the public health and environmental effects of improper waste disposal to the land come under serious study. This problem is manifested in groundwater contamination by leachate from landfills, surface water contamination via runoff, air pollution via open burning and evaporation, food contamination via improper storage, and, of course, personal injury via direct contact and explosions which may result from the mixing of wastes in landfill operations.

This problem has both short-term acute effects and longer-term chronic effects. It takes decades, in some cases, for hazardous compounds which have been buried in the land to leach through the soil into our surface and groundwater supplies.

A handicap to any hazardous waste management approach is the lack of reasonably accurate predictions of the noxious influence of a large array of substances with chronic risks of intoxication. Most of the tolerable concentration figures refer to situations where industrial workers or craftsmen are exposed to one or a few specific trade risks, while understandably little is known about the combined influence of a multitude of pollutants and the long-term effects of micropollutants.

Sometimes it is useful to take the velocity of recirculation or the mean circuital period as a criterion for risk evaluation. The fastest circuits usually go by air. At the same time they are the hardest to control since air is ubiquitous and free flowing in every direction while polluted water is mostly confined to lines, ducts and rivers. Infiltration into used groundwater or wells is the second fastest circuit. Disposal by tipping on land can mean second or third velocity circuit grade, depending on where the leaching hazardous substances go.

Also the control of toxic wastes discharged to a sewage system is necessary in order to

- safeguard those who have to enter sewers for maintenance,
- protect the biological processes of treatment.
- meet river authority requirements in respect of specified toxic matter in the effluent.

To achieve control, a limitation on the amount of toxic effluent may be necessary.

The principal effect of toxic effluents will be felt in the biological stages of treatment, i.e. aerobic oxidation and anaerobic digestion. In respect of aerobic oxidation it is necessary to consider carbonaceous oxidation and nitrification, and possibly in special circumstances such processes as sulphur oxidation. In addition it may be necessary to consider other effects on treatment; for example, the effect on macrofauna and film accumulation in biological filters and the effect on protozoa in and final settlement of activated sludge.

In sludge digestion the stages of liquefaction, acid production and methane production are interrelated consecutive steps so that interference with any stage will lead to a breakdown of the whole process.

Toxic effluents may be divided into 2 classes:

(1) Waste which can be toxic but also may be amenable to biological treatment. Examples of these include (a) gas liquors containing phenolic substances, (b) plastics wastes containing phenols and formaldehyde, and (c) chemical manufacturing wastes, including those with sulphides.

(2) Wastes which are toxic but do not undergo biological oxidation. Examples include (a) cyanide, which is usually considered under this heading because it is unlikely to be a major constituent requiring oxidation, although the possibility of biological oxidation exists, (b) metals of which copper, nickel, zinc and chromium are the ones commonly of concern in sewage treatment, (c) organic substances which do not readily undergo biological oxidation, e.g. nitrophenols and some chlorinated organic substances, and (d) acid wastes or strongly alkaline wastes. Table 1 gives a list of non-radioactive hazardous compounds.

In considering the acceptance of toxic wastes, the capacity of a treatment works to accommodate effluents, the waste and the practicability of pretreatment will be important. For example, the toxicity of acid wastes and cyanide wastes can be so easily eliminated by neutralisation and alkaline chlorination respectively that this will nearly always be the approach.

Everybody knows that some streams and rivers are so highly polluted that their water may not be used for drinking purposes or, ultimately, for any kind of application. Legislation, however, differs from country to country. Some tolerate already helplessly polluted rivers or water basins, others prohibit every, even additional, sort of water pollution. A definite tendency towards the former way of thinking may be observed the nearer we approach the sea, which is commonly not regarded as an important link of the ecologic network. On the other hand, the discovery of micro-polluted fish, coastal pollution and other phenomena have shown the finite nature of the ocean.

Sludges, slurries, or dewatered solids containing toxic materials present an ever increasing problem of disposal. To many, any solid represents material that can be safely landfilled and forgotten. On the contrary, such solids may present potential sources of highly toxic pollution.

If pollution of the environment is to be controlled, it is essential not only to remove the toxic materials from industrial wastewaters before discharge, but also ensure that, once removed, they are prevented from reaching ground or surface water by another path.

Table 1. A Sample List of Non-radioactive Hazardous Compounds*

Miscellaneous Inorganics

Ammonium chromate
Ammonium dichromate
Antimony pentafluoride
Antimony trifluoride
Arsenic trichloride
Arsenic trioxide
Cadmium (alloys)
Cadmium chloride
Cadmium cyanide
Cadmium nitrate
Cadmium oxide
Cadmium phosphate
Cadmium potassium cyanide
Cadmium (powdered)
Cadmium sulphate
Calcium arsenate
Calcium arsenite
Calcium cyanides
Chromic acid
Copper arsenate
Copper cyanides
Cyanide (ion)
Decaborane
Diborane
Hexaborane
Hydrazine
Hydrazine azide
Lead arsenate
Lead arsenite
Lead azide
Lead cyanide
Magnesium arsenite
Manganese arsenate
Mercuric chloride
Mercuric cyanide
Mercuric diammonium chloride
Mercuric nitrate
Mercuric sulphate
Mercury
Nickel carbonyl
Nickel cyanide
Pentaborane-9
Pentaborane-11
Perchloric acid (to 72%)
Phosgene (carbonyl chloride)
Potassium arsenite
Potassium chromate
Potassium cyanide
Potassium dichromate
Selenium
Silver azide
Silver cyanide
Sodium arsenate
Sodium arsenite
Sodium bichromate
Sodium chromate
Sodium cyanide
Sodium momofluoroacetate
Tetraborane
Thallium compounds
Zinc arsenate
Zinc arsenite
Zinc cyanide

Halogens and Interhalogens

Bromine pentafluoride
Chlorine
Chlorine pentafluoride
Chlorine trifluoride
Fluorine
Perchloryl fluoride

Miscellaneous Organics

Acrolein
Alkyl leads
Carcinogens (in general)
Chloropicrin
Copper acetylide
Copper chlorotetrazole
Cyanuric triazide
Diazodintrophenol (DDNP)
Dimethyl sulphate
Dinitrobenzene
Dinitro cresols
Dinitrophenol
Dinitrotoluene
Dipentaerythritol hexanitrate (DPEHN)
GB (propoxy (2)-methylphosphoryl fluoride)
Gelatinized nitrocellulose (PNC)
Glycol dinitrate
Gold fulminate
Lead 2,4-dinitroresorcinate (LDNR)
Lead styphnate
Lewisite (2-chloroethenyl dichloroarsine)
Mannitol hexanitrate
Nitroaniline
Nitrocellulose
Nitrogen mustards (2,2',2" trichlorotriethylamine)
Nitroglycerin
Organic mercury compounds
Pentachlorophenol
Picric acid
Potassium dinitrobenzfuroxan (KDNBF)
Silver acetylide
Silver tetrazene
Tear gas (CN) (chloroacetophenone)
Tear gas (CS) (2-chlorobenzylidene malononitrile)
Tetrazene
VX (ethoxy-methyl phosphoryl N,N dispropoxy-(2-2), thiocholine)

Organic Halogen Compounds

Aldrin
Chlorinated aromaties
Chlordane
Copper acetoarsenite
2,4-D (2,4-dichlorophenoxyacetic acid)
DDD
DDT
Demeton
Dieldrin
Endrin
Ethylene bromide
Fluorides (organic)
Guthion
Heptachlor
Lindane
Methyl bromide
Methyl chloride
Methyl parathion
Parathion
Polychlorinated biphenyls (PCB)

* Source: OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS. Report to Congress; disposal of hazardous waste. Environmental Protection Agency Publication No. SW-115. Washington, U.S. Government Printing Office, 1974. 110 p.

Most reactions, by which insoluble sludges are formed, are reversible if the conditions in the water in contact with the sludge change sufficiently. Variations in pH, in the concentration of ammonia (which can dissolve most toxic metals by forming water soluble complexes), in temperature or in the presence of oxidising compounds are some of the parameters that can produce toxic concentration of metals in the leachate.

These possibilities require that sludges be segregated by class, that close control of landfill conditions be practised and that adequate surveillance of the leachate be maintained. Treatment of toxic leachate may be required if the precautions taken are not adequate.

There is no "master list" of substances or compounds which are hazardous when placed onto or under the land surface. Table 1 identifies, however, a number of likely candidates. Numerous wastes contain such compounds in quantities which render the waste unacceptable for normal methods of waste management and disposal. Examples of industrial sources of such wastes are shown in Table 2. Of course, this is a sample list and there are many other industries which produce hazardous wastes. A more extensive list of hazardous waste substances was published, for instance, in the 1974 California Guidelines for the Handling of Hazardous Wastes.

Table 2. Presence of Representative Hazardous Substances in Waste Streams of Selected Industries*

	Hazardous substances										
Industry	As	Cd	Chlorinated hydrocarbons +	Cr	Cu	Cyanides	Pb	Hg	Miscellaneous organics‡	Se	Zn
Mining and metallurgy	x	x		x	x	x	x	x		x	x
Paint and dye		x		x	x	x	x	x	x	x	
Pesticide	x		x			x	x	x	x		x
Electrical and electronic			x		x	x	x	x		x	
Printing and duplicating	x			x	x		x		x	x	
Electroplating and metal finishing		x		x	x	x					x
Chemical manufacturing			x	x	x			x	x		
Explosives	x				x		x	x	x		
Rubber and plastics			x			x		x	x		x
Battery		x					x	x			x
Pharmaceutical	x							x	x		
Textile				x	x				x		
Petroleum and coal	x		x				x				
Pulp and paper								x	x		
Leather				x					x		

* Source: OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS. Report to congress; disposal of hazardous wastes. Environmental Protection Agency Publication No. SW-115. Washington, U.S. Government Printing Office, 1974. 110 p.

+ Including polychlorinated biphenyls.

‡ For example, acrolein, chloropicrin, dimethyl sulphate, dinitrobenzene, dinitrophenol, nitroaniline, and pentachlorophenol.

Many wastes when contacted or mixed with others at the waste management facility or for transport purposes, can produce hazardous situations through heat generation, fires, explosions, or release of toxic substances. Below is a summary of potentially non-compatible waste materials and a list of guidelines in their handling and disposal. (Source: California Guidelines for the Handling of Hazardous Wastes, 1974)

LIST OF POTENTIALLY NON-COMPATIBLE WASTES

<u>Group 1-A</u>

Alkaline caustic liquids
Alkaline cleaner
Alkaline corrosive liquids
Alkaline corrosive battery fluid
Caustic wastewater
Lime sludge and other corrosive alkalis
Lime wastewater
Lime and water
Spent caustic

<u>Group 1-B</u>

Acid sludge, acid tar
Acid and water
Battery acid
Chemical cleaners
Electrolyte, acid
Etching acid liquid or solvent
Liquid cleaning compounds
Pickling liquor and other corrosive acids
Sludge acid
Spent acid
Spent mixed acid
Spent sulphuric acid

<u>Potential consequences</u>: Heat generation, violent reaction.

<u>Group 2-A</u>

Asbestos waste and other toxic wastes
Beryllium wastes
Unrinsed pesticide containers
Waste pesticides

<u>Group 2-B</u>

Cleaning solvents
Data processing liquid
Obsolete explosives
Petroleum waste
Refinery waste
Retrograde explosives
Solvents
Waste oil and other flammable and explosive wastes

<u>Potential consequences</u>: Release of toxic substances in case of fire or explosion.

<u>Group 3-A</u>

Aluminium
Beryllium
Calcium
Lithium
Magnesium
Potassium
Sodium
Zinc powder and other reactive metals and metal hydrides

<u>Group 3-B</u>

Any waste in Group 1-A or 1-B

Potential consequences: Fire or explosion. Generation of flammable gas.

Group 4-A	Group 4-B
Alcohols	Any concentrated waste in Groups 1-A or 1-B
Water	Calcium
	Lithium
	Metal hydrides
	Potassium
	Sodium
	SO_2Cl_2, $SOCl_2$, PCl_3, CH_3SiCl_3, and other water-reactive wastes

Potential consequences: Fire, explosion, or heat generation. Generation of flammable or toxic gasses.

Group 5-A	Group 5-B
Alcohols	Concentrated Group 1-A or 1-B wastes
Aldehydes	Group 3-A wastes
Halogenated hydrocarbons	
Nitrated hydrocarbons and other reactive organic compounds and solvents	
Unsaturated hydrocarbons	

Potential consequences: Fire, explosion, or violent reaction.

Group 6-A	Group 6-B
Spent cyanide solutions	Group 1-B wastes

Potential consequences: Generation of toxic hydrogen cyanide gas.

Group 7-A	Group 7-B
Chlorates and other strong oxidizers	Acetic acid and other organic acids
Chlorine	Concentrated mineral acids
Chlorites	Group 2-B wastes
Chromic acid	Group 3-A wastes
Hypochlorites	Group 5-A wastes and other flammable and combustible wastes.
Nitrates	
Nitric acid, fuming	
Perchlorates	
Permanganates	
Peroxides	

Potential consequences: Fire, explosion, or violent reaction.

GUIDELINES FOR THE HANDLING AND DISPOSAL OF NON-COMPATIBLE WASTES

1. Non-compatible wastes should not be mixed in the same transportation or storage container.

2. A waste should not be added to an unwashed transportation or storage container that previously contained a non-compatible waste.

3. Non-compatible wastes should not be combined in the same pond, landfill, soil-mixing area, well, or burial container. An exception is the controlled neutralisation of acids and alkalis in disposal areas. Containers which hold non-compatible wastes should be well separated by soil or refuse when they are buried. Ideally, separate disposal areas should be maintained for non-compatible wastes.

4. Non-compatible wastes should not be incinerated together. An exception is the controlled incineration of pesticides and other toxic substances with flammable solvents.

These guidelines do not apply to any hazardous waste generator, transporter, or disposer or any person involved in hazardous waste management who combines hazardous wastes for neutralisation, detoxification or experimantal purposes providing that the lives and health of personnel involved and of the public are protected by controlling volumes, flow rates, constraints, vessel configurations, temperatures, and vents during the process or experiment so that uncontrollable reaction, fire, explosion, heat generation, or release of toxic materials does not occur.

In order to classify industrial waste it is necessary to identify it. Today's habit and legal situation in most countries is that waste of unknown character accepted by public disposal organisations should as a rule be identified by its supplier. Only in a few countries, however, a regulation exists compelling people to identify their own wastes, if disposed of privately. This situation is unsatisfactory because in case of damage the damaged person or State has to inquire about the possible nature of the pollution.

Several industrialised countries therefore tend to impose rigid controls on the flow of all relevant hazardous waste streams from the source to ultimate disposal. When enacting legislation and fixing guidelines for hazardous waste handling and disposal one has to bear in mind the following consequences:

- Lenient tolerance limits and indulgent rules stimulate increasing waste loads and waste engendering processes.

- Accurate tolerance limits and strict regulations cause higher production costs, thus reducing the competitive standard of a noxious waste-causing product or even totally eliminating such a product from the market. But the alternative cost - the environmental and health damage we will incur if dangerous materials continue to be discarded irresponsibly - is infinitely greater.

The Federal Republic of Germany, for example, enacted in 1977/78 2 statutory orders on hazardous waste, which comprise a listing of 34 identified waste streams that have to be handled and disposed of with special precaution and became subject to a book keeping system designed to control their whereabouts from source via transport (trip tickets) to disposal.

To safeguard public health and the environment, and also conserve resources, mazimum use should be made of existing technology to

- reduce the amount of hazardous waste generated in the first place;
- concentrate wastes (through evaporation, precipitation, other techniques) at the source to reduce handling and transport problems;
- stimulate "waste exchange" - one factory's hazardous wastes can become another's feedstock; for instance, acid and solvent wastes from some industries can be utilised by others;
- recapture and recycle metals, the energy content, and other useful resources contained in the wastes;
- destroy some hazardous wastes in special incinerators;
- detoxify and neutralise other wastes destined for land disposal; most non-radioactive wastes can be rendered harmless;
- build specially designed landfills, cut off from groundwater and properly monitored and secured, for hazardous materials that have to be buried in the ground.

No single treatment process for hazardous wastes can perform all necessary functions, i.e. volume reduction, component separation, detoxification, and materials or energy recovery. A series of several processes are generally required for adequate treatment. The general applicability of various treatment processes to types and forms of hazardous waste has been determined (Table 3). Many of these processes have been utilised previously for managing hazardous waste in industry and government. Several processes have capabilities for resource recovery. Selection of appropriate methods depends upon the type, form, and volume of the waste, and the relative economics of the processes.

Fig. 1 shows schematically the basic treatment and disposal options for non-radioactive wastes based on the present state of the art. The most commonly applied chemical treatment processes are:

- Neutralization of acids and alkalis.
- Oxidation of cyanide and nitrite (commonly encountered in metal finishing effluents) by sodium hypochlorite.

Table 3. Functions, Applicability, and Resource Recovery Capability of Currently Available Hazardous Waste Treatment and Disposal Processes*

Process	Functions performed +	Types of waste ‡	Forms of waste **	Resource recovery capability
Physical treatment:				
Carbon sorption	VR,Se	1,3,4,5	L,G	Yes
Dialysis	VR,Se	1,2,3,4	L	Yes
Electrodialysis	VR,Se	1,2,3,4,6	L	Yes
Evaporation	VR,Se	1,2,5	L	Yes
Filtration	VR,Se	1,2,3,4,5	L,G	Yes
Flocculation/settling	VR,Se	1,2,3,4,5	L	Yes
Reverse osmosis	VR,Se	1,2,4,6	L	Yes
Ammonia stripping	VR,Se	1,2,3,4	L	Yes
Chemical treatment:				
Calcination	VR	1,2,5	L	
Ion exchange	VR,Se,De	1,2,3,4,5	L	Yes
Neutralization	De	1,2,3,4	L	Yes
Oxidation	De	1,2,3,4	L	
Precipitation	VR,Se	1,2,3,4,5	L	Yes
Reduction	De	1,2	L	
Thermal treatment:				
Pyrolysis	VR,De	3,4,6	S,L,G	Yes
Incineration	De,Di	3,5,6,7,8	S,L,G	Yes
Biological treatment:				
Activated sludges	De	3	L	No
Aerated lagoons	De	3	L	No
Waste stabilization ponds	De	3	L	No
Trickling filters	De	3	L	No
Disposal/storage:				
Deep-well injection	Di	1,2,3,4,6,7	L	No
Detonation	Di	6,8	S,L,G	No
Engineered storage	St	1,2,3,4,5,6,7,8	S,L,G	No
Land burial	Di	1,2,3,4,5,6,7,8	S,L	No
Ocean dumping	Di	1,2,3,4,7,8	S,L,G	No

* Sources: TRW Systems Group. Recommended methods of reduction, neutralisation, recovery or disposal of hazardous waste. Vol. 1-16. Springfield, National Technical Information Service, 1973. PB-224 579-set/AS. ARTHUR D. LITTLE, INC. Alternatives to the management of hazardous wastes at national disposal sites. Vols. 1 and 2. U.S. Environmental Protection Agency, 1973. Available from National Technical Information Service, Springfield, Va., as PB-225 164/AS. BATTELLE PACIFIC NORTHWEST LABORATORIES. Program for the management of hazardous wastes. Vols. 1 and 2. U.S. Environmental Protection Agency. (Available through the National Technical Information Service, Springfield, Va.) (Inpress.)

\+ Functions: VR, volume reduction; Se, separation; De, detoxification; Di, disposal; and St, storage.

‡ Waste types: 1, inorganic chemical without heavy metals; 2, inorganic chemical with heavy metals; 3, organic chemical without heavy metals; 4, organic chemical with heavy metals; 5, radiological; 6, biological; 7, flammable; and 8, explosive.

** Waste forms: S, solid; L, liquid; and G, gas.

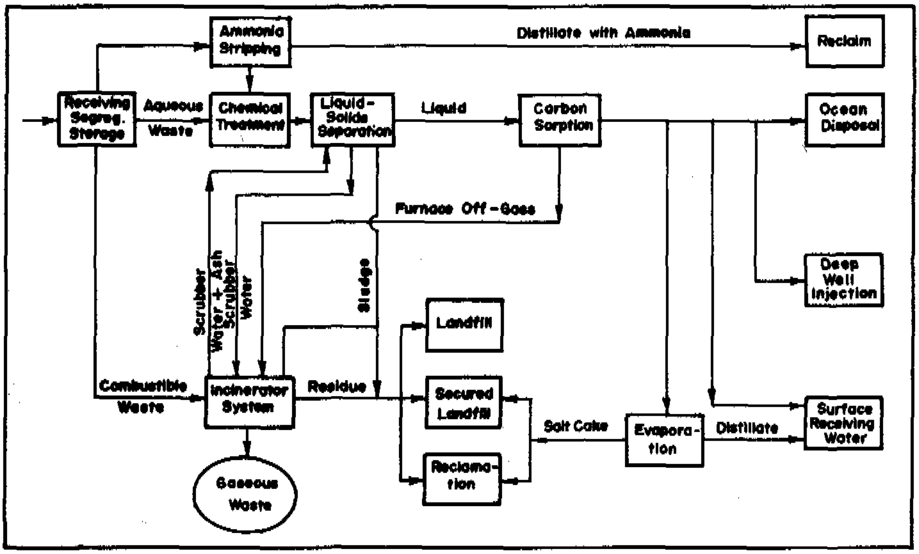

Fig. 1. Treatment and Disposal Options for Non-radioactive Hazardous Wastes (Source: Programme for the Management of Hazardous Wastes, Batelle Memorial Institute Pacific Northwest Laboratories, Richland, Wash., 1973)

- Reduction of oxidising agents such as chromic acid, chromate or persulphate. This can easily be carried out by a range of reducing agents, i.e. by sodium sulphite or sulphur dioxide,
- Chemical precipitation of metal hydroxides by reaction with soda, calcium hydroxide or sodium hydroxide. In the presence of ammonia, copper and nickel for example, form preferentially a soluble metal-ammonia complex and the hydroxides cannot easily be precipitated. In this case the metals can be precipitated alternatively as sulphides which are extremely insoluble.
- Oxidation of organics by chlorine, ozone, peroxide or permanganate. The oxidant of choice depends on the least expensive effective procedure.

Liquid-solids separation is accomplished in sedimentation/flocculation tanks. Dewatering of sludges can be achieved by filtering devices and by evaporation. The wastewater separated from sludges frequently needs further treatment before discharge. In arid climate zones natural evaporation may be applicable to sludge treatment.

Carbon absorption can remove hazardous organics from wastewater. After carbon filtration, the carbon may be regenerated by heat, pressure, and steam.

Special treatments such as ammonia stripping are required for some wastes, but these are of secondary interest.

Solvents from certain wastes (e.g. dry cleaning wastes) can be reclaimed by distillation.

Mineral oil emulsions can be separated by a number of processes.

Waste mineral oils can be rerefined for reclamation of lubricant oil and gas oil.

The mineral oil content of certain solid wastes, especially spent clays, can be extracted and the solid residue disposed of by landfill.

Some scrubber sludges as well as certain electroplating sludges contain high concentrations of heavy metals. The increasing value of metals such as copper and nickel may make their extraction practical. This possibility will not decrease sludge volume though, since only the metals are leached out and the added acid and residue will have to be safely disposed.

Incineration of combustible hazardous wastes (mainly organic pesticides and explosives) and spent carbon can eliminate organic hazardous wastes and reduce waste volume. Incineration is generally unsafe when heavy metals like mercury and arsenic are present and should be avoided. Incinerator ash residues must be disposed into sanitary landfills without contact with groundwater or surface water.

For the destruction of selected chlorinated hydrocarbon wastes incineration at sea on board special combustion ships may be the best solution whereby the bulk of the hydrochloric acid fumes evolving from the furnace is absorbed and neutralised by the seawater.

Ocean disposal by dumping seems to be a method which arouses a strong reaction from the public and there are a number of activities on international level aiming to restrict dumping of hazardous wastes at sea. A review of criteria for marine waste disposal as applied by various countries - Southeast Asian countries included - was published in the Proceedings of the 2nd International Congress on Marine Pollution and Marine Waste Disposal 1973. For certain wastes, however, dumping at sea may be the most appropriate disposal method, if applied with adequate care and properly controlled. In the Federal Republic of Germany, for example, acid waste from titanium dioxide production is diluted and then discharged into the propeller waters of the disposal ship while in motion so that rapid dispersal and neutralisation of the sulphuric acid and oxidation of the ferrous sulphate content by the sea water are guaranteed.

Similar considerations apply to the technology of deep well disposal whereby waste liquids are injected into deep aquifers (say between 500 and 1,500 metres depth) below the reservoirs of usable ground water.

The disposal of hazardous wastes in sanitary landfills has been a common practice but requires precautionary measures to avoid operator exposure and prevent adverse environmental impacts. Because of the nature of many types of hazardous wastes, it is important to ensure that they do not leach into underground water supplies. The conclusion was drawn from an extensive research programme of the United Kingdom into the behaviour of hazardous wastes in landfill sites that sensible landfill is realistic and an ultra-cautious approach to landfill of hazardous and other types of waste is unjustified. Experience over a long period of time has shown that very few documented cases of significant groundwater contamination due to landfills have occurred. Preferably landfill sites for hazardous wastes should be located on impervious soils or rocks or on formations that are not water bearing or have unusable groundwater beneath them. They must also provide protection from flooding, surface runoff or drainage, and all fill seepage is treated or limited to the fill site. Many times underdrain systems are necessary in these sites to insure the collection of all leachate for further treatment.

For many types of hazardous wastes, however, co-disposal with ordinary waste at general though controlled landfill sites is acceptable. In these cases attention is drawn to the advantages of an unsaturated zone beneath a landfill, namely the delay mechanisms and the increased opportunities or attenuation of leachates by chemical and biochemical processes. At such sites a greater decrease in TOC than in chloride (attenuated only by dilution) occurs. At sites where leachate movement took place under saturated conditions (i.e. no unsaturated zone) the deleterious effect of high hydraulic loadings caused by the discharge of excessive amounts of liquid wastes has been confirmed. Although the significance of biochemical processes in the unsaturated zone is not completely understood, the substantial reductions of TOC which were often noted were sufficient to allow any residual 'tail' to be attenuated to background concentrations in groundwater.

Attenuation mechanisms (defined broadly to include dilution) are available in the landfill and underlying strata, which are extremely beneficial if used with discretion. Mixed mineralogies such as clay with sand lenses and sand with clay have been shown to attenuate various chemical species.

Processes such as sorption and ion-exchange have been shown to prevent the migration of leachate constituents from the landfill. Domestic waste has a substantial retention capacity for mercury, oils and PCB's, but not for phenols.

The rate and degree of mixing of leachates and groundwater in the saturated zone may vary considerably, and aqueous wastes are attenuated more easily compared to oil/water mixtures.

To ensure the proper admixture of hazardous wastes into other solid waste in a sanitary landfill, precautions should be taken to ensure that the hazardous wastes are adequately spread. Some landfills require a separate site area in which hazardous wastes are handled specially and where the operators have special procedures for mixing and handling. One method is to prepare a sump to receive the hazardous wastes on the sloping working face of the landfill. A portion of the landfill solid wastes is compacted to form a sump and protective solid waste and earth berms are provided to contain the liquid hazardous wastes. Once the hazardous wastes are disposed into the sump, additional non-hazardous solid waste is placed for absorption and burial. Additional solid waste may then be covered using normal fill practices.

Also the percolation of certain types of liquid wastes from ditches excavated in the solid refuse bed in a fenced area of a landfill may be a method of choice, provided the wastes are compatible and the system is not overloaded. Normal solid wastes (commercial, residential) can absorb as much as 50 - 100 per cent by weight of liquid.

Many hazardous wastes arrive in containers that may present safety problems during landfilling operations. Containers filled with liquids or compressed gases may burst when struck by heavy landfill equipment, releasing the gases or splashing-liquid on equipment and/or operators. Explosions and fires may also result. Therefore drums should be emptied before being crushed by landfill equipment. Some prepackaged containers that may not be emptied before disposal require special care. They should be disposed of without being punctured and should be buried well under other solid waste so that when they eventurally deteriorate and release their contents, they are absorbed and contained by the surrounding refuse.

Extreme caution should be exercised during fill placing, spreading, compaction, and covering operations to prevent harm to the operator or equipment through exposure to toxic solids, liquids, dusts, fumes, and gases. Self-contained breathing equipment should be used by the operator or at a minimum should be available in case of emergency. Other persons using the disposal site should be segregated from the hazardous waste disposal area, and scavenging should be strictly prohibited. Equipment should be coated with anti-corrosive materials, and a systematic cleaning and maintenance programme must be employed to minimise adverse effects. Medical and standby safety equipment must be provided for the landfill operators. All hazardous wastes handled must be clearly identified and disposed in a technologically correct manner.

REFERENCES

Assessing Potential Ocean Pollutants, (1975) A Report of the Study Panel on Assessing Potential Ocean Pollutants. National Academy of Sciences, Washington, D.C., 438 pp.

California Guidelines for the Handling of Hazardous Wastes, (1974) California Department of Health, June 1974, 39 pp.

Code of Good Practice for Mangement of Hazardous and Toxic Wastes at Federal Establishments, (1977) Environment Canada, Environmental Protection Service, Toronto, 171 pp.

Control of Hazardous Material Spills. Proceedings of the 1974 National Conference on Control of Hazardous Material Spills. American Institute of Chemical Engineers, New York, N.Y., 1974, 377 pp.

Department of the Environment, Scottish Development Department, (1970) Disposal of Solid Toxic Wastes. The Report of the Technical Committee on the Disposal of Solid Toxic Wastes. Her Majesty's Stationery Office, London, 106 pp.

Department of the Environment, (1976) Reclamation, Treatment and Disposal of Wastes. An Evaluation of Available Options. Waste Management Paper No. 1, Her Majesty's Stationery Office, London, 42 pp.

Department of the Environment, (1978) Wastes from the Manufacture of Pharmaceuticals, Toiletries and Cosmetics. Waste Management Paper No. 19, Her Majesty's Stationery Office, London, 49 pp.

Department of the Environment, (1976) Polychlorinated Biphenyl (PCB) Wastes. A Technical Memorandum on Reclamation, Treatment and Disposal Including a Code of Practice. Waste Management Paper No. 6, Her Majesty's Stationary Office, London, 19 pp.

Department of the Environment, (1976) Mineral Oil Wastes. A Technical Memorandum on Arisings, Treatment and Disposal In luding a Code of Practice. Waste Management Paper No. 7, Her Majesty's Stationery Office, London, 28 pp.

Department of the Environment, (1978) Co-operative Programme of Research on the Behaviour of Hazardous Wastes in Landfill Sites. Final Report of the Policy Review Committee. Her Majesty's Stationery Office, London, 1978, 169 pp.

Department of the Environment, (1978) Metal Finishing Wastes. A Technical Memorandum on Arisings, Treatment and Disposal including a Code of Practice. Waste Management Paper No. 11, Her Majesty's Stationery Office, London, 50 pp.

Department of the Environment, (1977) Mercury-bearing Wastes. A Technical Memorandum on Storage, Handling, Treatment, disposal, and Recovery of Mercury including a Code of Practice. Waste Management Paper No. 12, Her Majesty's Stationery Office, London, 1977, 75 pp.

Department of the Environment, (1977) Tarry and Distillation Wastes and other Chemical Based Residues. A Technical Memorandum on Arisings, Treatment and Disposal Including a Code of Practice. Waste Management Paper No. 13, Her Majesty/s Stationery Office, London, 1977, 45 pp.

Department of the Environment, (1978) Wastes from Tanning, Leather Dressing and Fellmongering. A Technical Memorandum on Recovery, Treatment and Disposal including a Code of Practice. Waste Management Paper No. 17, Her Majesty's Stationery Office, London, 40 pp.

Department of the Environment, (1977) Solvent Wastes (excluding Halogenated Hydrocarbons). A Technical Memorandum on Reclamation and Disposal Including a Code of Practice, Waste Management Paper No. 14, Her Majesty's Stationery Office, London, 33 pp.

Department of the Environment, (1976) Heat-Treatment Cyanide Wastes. A Technical Memorandum on Arisings, Treatment and Disposal Including a Code of Practice. Waste Management Paper No. 8, Her Majesty's Stationery Office, London, 15 pp.

Department of the Environment, (1976) Halogenated Hydrocarbon Solvent Wastes from Cleaning Processes. A Technical Memorandum on Reclamation and Disposal Including a Code of Practice. Waste Management Paper No. 9, Her Majesty's Stationery Office, London, 1976, 16 pp.

Disposal in the Marine Environment, (1976) An Oceanographic Assessment. Nagional Academy of Sciences, Washington, D.C., 76 pp.

Fields and Lindsey A.W. (1975) Landfill disposal of Hazardous Wastes, a Review of Literature and Known Approaches. U.S. Environmental Protection Agency, EPA - 530/SW - 165, Washington, D.C., 36 pp.

Fuller W.H. (editor), (1976) Residual Management by Land Disposal. Proceedings of the Hazardous Waste Research Symposium. U.S. Environmental Protection Agency, EPA - 600/9 - 76 - 015, Washington, D.C., 270 pp.

Irwin W.A. and Liroff R.A., (1974) Used Oil Law in the United States and Europe. U.S. Environmental Protection Agency, EPA - 600/5 - 74 - 025, Washington, D.C., 289 pp.

Laboratory Waste Disposal Manual, (1974) Manufacturing Chemists Associaiion, Washington, D.C., 176 pp.

Marine Pollution and Marine Waste Disposal, (1973) Proceeding of the 2nd International Congress, San Remo, 17-21st December, 1973. Pergamon Press, Oxford, New York, Toronto, Sydney, Paris, Braunschweing, 1975, 487 pp.

Pilot Study "Disposal of Hazardous Wastes": Landfill, (1977) Committee on the Challenges of Modern Society, North Atlantic Treaty Organisation, Report No. 64, Brussels, 1977, 90 pp.

Pilot Study "Disposal of Hazardous Wastes": Recommended Procedures for Hazardous Waste Management, (1977) Committee on the Challenges of Modern Society, North Atlantic Treaty Organisation, Report No. 62, Brussels, 95 pp.

Pilot Study "Disposal of Hazardous Wastes": Transportation, (1977) Committee on the Challenges of Modern Society, North Atlantic Treaty Organisation, Report No. 68, Brussels.

Pilot Study "Disposal of Hazardous Wastes": Organisation, (1977) Committee on the Challenges of Modern Society, North Atlantic Treaty Organisation, Report No. 63, Brussels, 108 pp.

Powers Ph.W., (1976) How to Dispose of Toxic Substances and Industrial Wastes. Environmental Technology Handbook No. 4, Noyes Data Corporation, Park Ridge, N.J. (USA), 497 pp.

Reed A.W., (1975) Ocean Waste Disposal Practices. Noyes Data Corporation, Park Ridge, N.J. (USA), 336 pp.

Reeder L.B. et al., (1977) Review and Assessment of Deep-Well Injection of Hazardous Waste. U.S. Environmental Protection Agency, EPA - 600/2 - 77 - 029 a, Cincinnati, Ohio, Volumes 1-4, 1446 pp.

Report to Congress: Disposal of Hazardous Wastes, (1974) U.S. Environmental Protection Agency, Publication SW-115, Washington, D.C., 110 pp.

TRW Systems Group, (1973) Recommended Methods of Reduction, Neutralization, Recovery or Disposal of Hazardous Waste. Volume I Summary Report, 305 pp.

WHO Expert committee, (1971) Solid Wastes Disposal and Control. World Health Organisation, Technical Report No. 484, Geneva, 34 pp.

WASTE MANAGEMENT PLANNING: A REVIEW OF THE KEY ELEMENTS IN WASTE MANAGEMENT PLANNING AND DECISION MAKING

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INTRODUCTION

The aim of waste management planning is to ensure that every day, this year, next year and in 10 years' time waste is collected, handled and disposed of as efficiently, as economically and with as little environmental impact as practical.

As part of the exercise, the waste management planner must examine and take account of a wide range of activities not always directly related to the day-to-day collection and disposal of waste: population changes, housing and industrial developments, water requirements, central government policy objectives on resource recovery, etc.

And it is a continuous process. The quantity, composition and location of waste arising changes and the useful life of most equipment and disposal facilities is limited. So the waste management planner must not only ensure that today's operation runs smoothly but he must also be responsive to change. This means that relevant data must be reviewed and plans updated regularly.

The aim of this paper is to review the main tasks involved in the preparation of a waste management plan. This is done under the following headings:

- Identification of objectives and constraints,
- Data collection,
- Analyses of the principal options,
- The decisions and the process of review.

The principal steps are shown in Fig. 1. A more detailed scheme is included in Fig. 2.

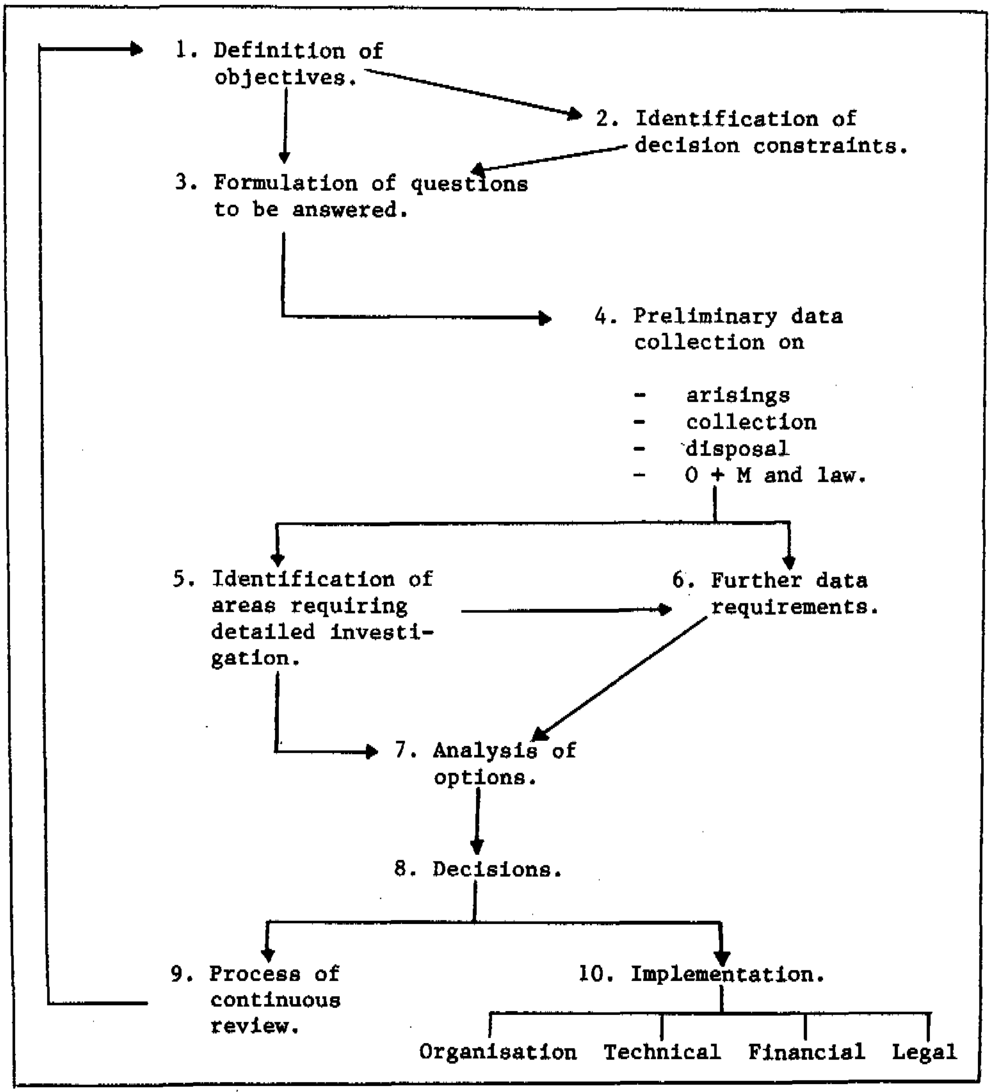

Fig. 1. Principal Steps in the Development of a Waste Management Plan

OBJECTIVES AND CONSTRAINTS

Objectives

It is the objectives of the waste management plan and the constraints within which it must operate that provide the framework for the eventual decisions. Failure to identify the objectives and constraints accurately at the outset can cause considerable confusion when defining the most appropriate collection or disposal options. This problem is discussed further below.

The objectives should identify the purpose of the waste management plan and should in particular note what the plan is to emcompass in terms of geographical area, types of waste and a time horizon for the plan.

The geographical limits to be included in the plan are of particular importance either where a number of small administrative units are grouped closely together or where there is a large metropolitan administrative unit bounded by rural areas. In either case a regional approach should be considered for the purposes of planning: not necessarily because it will prove desirable to bring the areas together as a single operation but often shared disposal facilities can make real sense from a management and economic viewpoint.

It is also important to identify what types of waste are to be included in the plan. There is a tendency to think mainly of household and shop waste (often because that is the only type of waste for which the public authority has responsibility) and ignore waste arising from industry and building operations and such waste as sludge from sewage treatment plants, animal wastes from intensive farming and small urban farms and other wastes from special local activities such as slaughterhouses, ports etc. These wastes may fall outside the responsibility the public authority but they will still require disposal and as such will be competing for local sites. It should be stressed that no amount of regulation will prevent illegal and haphazard dumping if local disposal facilities are inadequate or not easily accessible.

One cannot be dogmatic about the time horizon for waste management planning. This will depend very much on local circumstances and needs. Probably certain elements in the plan such as waste quantities, long-term availability and capacity of disposal sites should be considered over a longer time horizon than other considerations. This is because final disposal of the wastes is an overriding factor in any plan and is likely to influence the approach adopted so far as collection and transport are concerned.

Constraints

There are a number of constraints that will tend to limit the available alternatives. By recognising these at the outset, a great deal

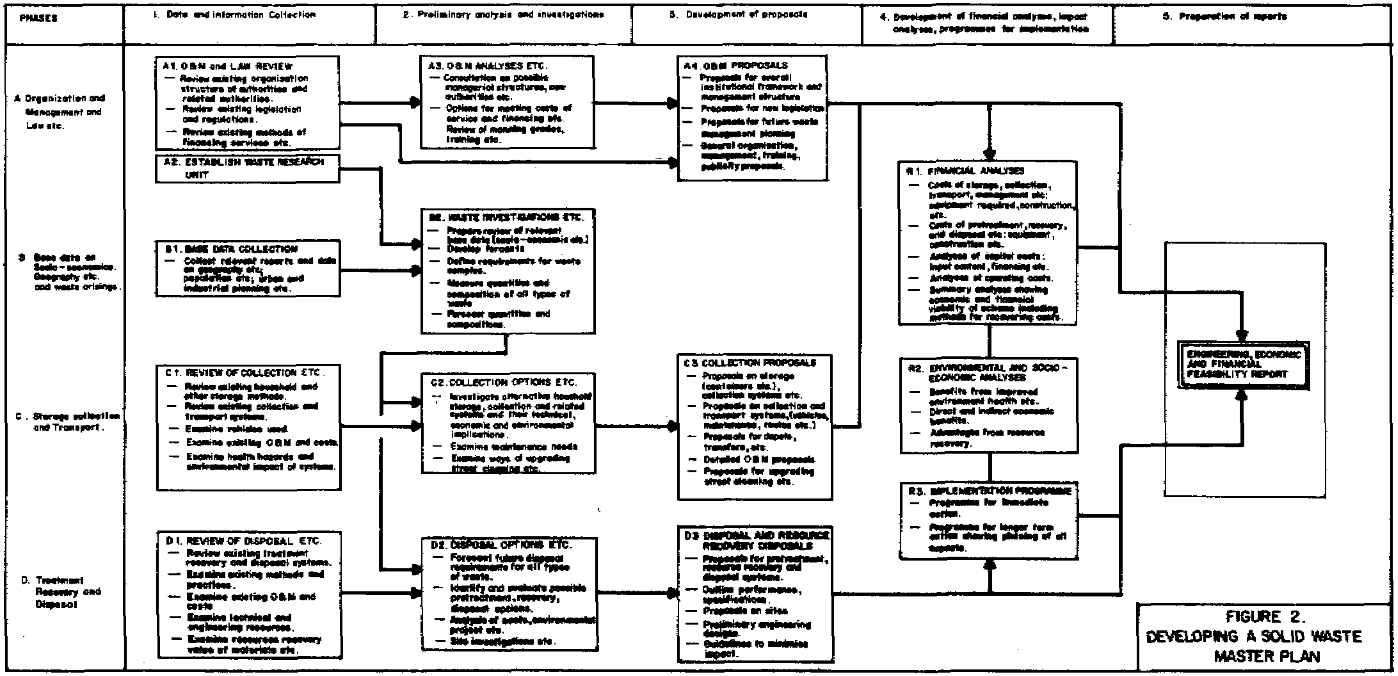

FIGURE 2.
DEVELOPING A SOLID WASTE MASTER PLAN

of unnecessary work can be avoided; their recognition will also be of assistance in the eventual selection of the appropriate collection and disposal options.

Some such constraints may be the local political realities: for example, there may be no way of gaining co-operation between 2 neighbouring towns in the development of a regional plan; and there is no merit in developing a plan that ignores such factors since the result is that the plan will not be implemented and a lot of work will be wasted.

General policy objectives must also be taken into account and to some extent these also operate as constraints in so far as they provide guidelines for decision making. Such policy objectives may arise from central or local government and may cover:

- Employment: for example the need to maximise wherever possible the numbers employed;

- Resource recovery: minimising waste at all levels even where the financial return is doubtful is often considered desirable for other reasons (savings in imports etc.);

- Environmental improvement: minimising health and environmental impact from waste is always one of the objectives of waste management plan but this may for policy reasons need to be given special emphasis in which case extra resources must be made available for, for example, street cleaning or enforcement to prevent illegal dumping.

Financial constraints There may be overall limits imposed on total expenditure or specific limits on capital expenditure or on the import content of any expenditure. If either of the latter of the case, there is little value in considering capital-intensive high-technology solutions unless the advantages appear so overwhelming that even a Minister of Finance would be impressed.

Manpower constraints There may be a shortage of all types of manpower (for example the productive sector may be able to reward workers more highly than the public service sector) but it is more likely that there will be a shortage of a particular type of skill. If for example there is a shortage of technicians then this must be taken into account in the planning and solutions must be found which either require the minimum use of technicians or provide for the necessary training.

Land-use constraints Waste management problems tend to be worse in urban and suburban areas and it is here that shortage of land will also be most acute. Where some form of structure plan has already been prepared, some information will be available on the possibilities for space for transfer stations, depots, landfill sites etc. But the waste management planner will be competing for land with many other types of user. Existing land uses will probably provide the best guide of the areas that are likely to prove more or less acceptable. Waste disposal sites are clearly not compatible with, for example, aircraft flight paths near airports (because of bird strike dangers) and extra care is required if they are to be sited close to residential developments.

Environmental constraints Disposal sites give rise to leachate problems so site selection must take account of the hydrogeological characteristics of the area and the location of aquifers and wells. In most parts of the world good quality potable water is at a considerable premium and as such is a major factor in identifying suitable areas for landfill.

Air quality is an important environmental factor where incineration is under consideration. In some locations the emissions will be dispersed without any adverse impact; while elsewhere local topographical and meteorological circumstances can cause the emissions to give rise to considerable local nuisance even where reasonable air pollution controls have been installed. It is perhaps unfortunate that in those densely populated areas where incineration would make most sense, background levels of air pollution from cars, homes and industry make any additional source of air pollution particularly undesirable.

Local circumstances will dictate other constraints.

THE KEY QUESTIONS

Identification of the objectives and the principal constraints allow the planner to formulate a series of questions that will need to be answered during the course of the exercise.

These are likely to include:

(i) What are the existing quantities, composition and location of wastes requiring disposal? How are these likely to change?

(ii) How are the wastes at present collected? What are the principal problems and difficulties? What are the options of overcoming these problems and the cost of the options?

(iii) How are the wastes currently disposal of? What are the principal problems and difficulties? What are the options of overcoming these and at what cost?

(iv) Given the objectives and constraints of the plan and the costs, benefits and problems associated with collection and disposal, which of the available options would prove most appropriate?

(v) Is the existing organisation and management adequate for implementing the option selected? Is the available legislation and are the enforcement procedures adequate? How is the overall plan to be financed?

From the way the above questions are structured it will be seen that the approach requires an examination of existing problems and identification of the most cost-effective solutions (taking account of the objectives and constraints) for overcoming these. It is of course possible to tackle the waste management plan afresh. But in reality, unless one is planning a new town, there is always some form of waste management system in place and it tends to be more effective to upgrade and improve what exists taking account of the problems and previous experience rather than starting afresh. This approach also helps to focus the mind of the planner on what most needs to be done.

It will also be noted from the sequence of the questions that after the decisions have been taken in principle there is a further examination of organisation, management law and financing. While these have a bearing on the principal decisions themselves, nevertheless it is desirable to minimise the detail at the earlier stages until one has some idea of the overall approach to be adopted.

DATA COLLECTION

Essential Information Requirements

To answer the questions listed above, information will be required on:

- Population, housing, industrial and agricultural development etc.;
- Wastes arising, their quantity, composition and sources;
- Waste storage and collection: household and other storage methods, collection methods, available vehicles, vehicle maintenance, etc.;
- Treatment and disposal: existing methods, future capacities, plant life, local hydrogeology, etc.;
- Management and law: organisation, staffing, training, regulations and their enforcement etc.

This information will enable a preliminary assessment made of those areas where a detailed investigation is required either because the available data are inadequate; or because there are particular operational problems (e.g. maintenance of collection vehicles) that require special attention.

Shortage of Data

In the short term, considerable ingenuity must often be applied to collect the data on which to evaluate the local needs and the need for immediate action; in the longer term systems can be established that provide essential information on a regular basis.

In particular, there is often a shortage of information on quantity and composition of waste arising. There are a number of ways that a preliminary assessment can be made; these include:

- The use of per capita estimates from other local regions or comparable areas in other countries;
- Estimates of the amount collected by each collection vehicle over a period and aggregation of the results;
- Examination of the vehicles arriving at the local disposal sites, identifying the source and estimating the loads;
- Surveying and estimating the quantity of waste in the disposal sites and calculating a daily arising from information on when the site was started.

These approaches will only provide an approximate indication and the use of these figures for forecasting is fraught with potential pitfalls.

In particular, care must be taken to disaggregate the household from other wastes. This is important for 2 reasons:

- The rate of growth of the population will not necessarily be the same as growth in other sources of waste (industry, construction, agriculture etc.); so if the population is expected to increase by 20 per cent over the next 10 years it does not necessarily mean that total waste arising will increase by the same amount;
- For some treatment and recovery options (e.g. composting, energy and materials recovery) the waste composition is crucial: and it is not uncommon to find that waste planners when designing a composting plant, for example, have applied the figure for organic content of household waste (say 50 per cent) to the total waste arising whereas because of the presence of construction, industrial waste etc. the proportion could be only 25 per cent.

It is obviously important to have good data on waste arising so the necessary system should be established to collect the information on a regular basis. In addition, industrial waste arising should be estimated either by a questionnaire approach or, often more satisfactorily, by recording deliveries to disposal sites.

Reference was made above to "essential information requirements". One cardinal rule is not to collect data for the sake of it. It is often a very time-consuming and expensive exercise. The preliminary data collection stage is likely to have identified areas where there are specific problems and where data are required to monitor the situation (e.g. leachate from landfill) or to provide a solution (e.g. the number of households in a district where collective storage is required). From this specific data requirements can be listed. It is always useful to stop from time to time and ask the question: how is the information we are collecting going to be used?

Detailed investigation

Where specific problems have been identified, a more detailed investigation will be required to provide sufficient data on the options to enable an informed decision to be made.

There may be a shortage of landfill sites close to the waste arising. There would be then a number of options that will require investigation:

- Transfer the waste by road or by rail to a more distant site;
- Reduction of the quantity of waste requiring disposal either by incineration or by some form of resource recovery;
- Alternatively wastes from different sources could be separated so that inert wastes (some industrial wastes) go to sites that would be unsuitable for refuse.

For each alternative, information will be required on the technical viability (taking account of any land-use constraints) and the costs, benefits and impacts. In the case of resource recovery, it is essential that investigations are carried out to ensure that long-term outlets for the product are secured.

ANALYSES AND DECISIONS

Where a number of options are available (for example, possible disposal sites) it will be necessary to evaluate the capital and operating costs and the benefits and associated health and environmental impacts.

A word of caution about the conventional cost/benefit approach. It is often not practical to quantify the benefits and impacts in monetary terms. The effects should be identified for each of the options and should then be assessed against the background of the objectives and constraints which need to be satisfied. In other words, if resource recovery and minimising land use are important then each of the projects should be considered in relation to these factors.

Costs

There are however a number of general points regarding costing the alternatives that should be noted.

All elements in the system should be costed for each of the options, otherwise it is difficult to make comparison or to evaluate improvements in performance. For example:

- If the cost of incineration is compared with the cost of landfill, it is necessary that the cost of disposing of the residue from the incinerator (which may be up to 30-50 per cent of the original waste by weight) should be taken into account in the incineration cost;

- Compaction in the collection vehicle may be a viable alternative to normal collection and transfer so all the collection costs and transfer costs of each system should be evaluated in parallel.

Costs should be expressed in terms of cost per tonne of waste as this is a constant throughout the waste system. Volume changes, usually decreasing at each stage until it reaches a final compaction perhaps several years after disposal. Volume, not weight, however, is often a key determinant in judging capacities of vehicles and disposal sites.

In assessing the different costs of options, capital and operating costs should be "treated" in conformity with the accounting approach used by the public authorities. This means account must be taken of the way that capital costs are written off (over how many years, at what interest rate, etc.) as should any grants given by a central government agency for particular types of scheme (e.g. for energy projects).

Where a number of different options with different life times are under consideration, perhaps the best way of comparing the cost is to consider the Present Value of the alternatives: that is, discounting all the costs over the life time of the projects back to today's value. Otherwise it is very difficult to compare the cost, for example, of a composting plant (with a 20-year life) with a series of landfill sites which will need capital expenditure in 5, 10 and 15 years' time and will require new site equipment every 4 years or so.

Finally, in assessing the costs a number of assumptions will need to be made about future inflation rates, interest rates and exchange rates. In some countries these are of major importance in determining the financial attractiveness of a particular project. To examine their importance, it is necessary to look at the sensitivity of costs to variations in these factors.

DECISIONS

As has been stressed throughout this paper, the most appropriate solutions will be those that minimise the cost of waste management, provide long-term security of disposal and satisfy environmental and other objectives and constraints.

To assist the decision process, it may be useful to present the results of the analyses in the form of a matrix, with each of the options down one axis and the implications along the other.

The implications are likely to include:

- cost per tonne
- Present Value of scheme
- cost implication (capital cost, input content, annual operating cost and annualised capital plus operating cost)
- longer-term implications (life of scheme and effect on long-term management of local resources)
- environmental implications (water pollution, air pollution and proximity to residential areas, etc.)
- employment implications
- resource recovery implications, etc.

Information on each of the options and the extent to which they satisfy the constraints or objectives can be shown in the matrix. This allows the decision-maker to rapidly compare, for example, the environmental effects of each of the schemes.

Further matrices can be prepared to indicate in more detail the extent to which the options satisfy particular objectives or constraints and at what cost.

Clearly the least cost solution is not necessarily the most appropriate. The achievement of environmental objectives, for example, is likely to increase the cost and a decision will be required how far such improvements should go given additional cost. Similarly many resource recovery projects tend, in strict financial terms, to add to the cost of waste management; again, a decision is required taking account of the wider issues whether the additional cost is justified.

One other important factor which is often overlooked is the question of long-term security of disposal. In most cases, there is only one option for final disposal of all wastes and that is landfill. Even the most extensive resource recovery scheme for household wastes will leave some residue; and for many wastes there are no real recovery options. If there is an acute shortage of tipping space it is unrealistic to evaluate a site solely in terms of the actual cost of tipping there today; as in 5 years' time it may prove necessary to select a very expensive alternative when that particular site is full. For this reason it is essential to look at the options in the longer term and where capacity is short to take action now that will prolong life and minimise costs in the longer term.

Once the plan is complete it should if possible be published. This helps the public to understand how their problems are being dealt with and gives anyone whose interests may be affected a chance to discuss these with the authories.

But the plan itself is only the first stage. Progress must then be monitored and the plan regularly reviewed and when necessary changes made.

THE USE OF ECONOMIC ANALYSIS IN WASTE MANAGEMENT DECISION MAKING

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INTRODUCTION

Economic analysis is one of the fundamental tools required in waste management decision making. It is an essential aid in decisions as varied as:

- what method of disposal to use for a particular type of waste;
- where to locate waste handling facilities;
- evaluating options for resource recovery;
- assessing the net benefit to be obtained from higher standards of waste management, taking into account both financial costs and environmental impact.

Here some important general features of economic analysis are briefly discussed and then how this tool can be used in the field of waste management is examined. The method is illustrated with an example drawn from ERL's practical experience of using economic analysis to assist in waste management decision making.

THE FEATURES OF ECONOMIC ANALYSIS

Economic analysis is concerned with the assessment of the costs and benefits that are attached to any particular course of action. It provides a framework for bringing together the various elements that need to be taken into account in waste management decision making, from methods of handling waste to the amount of finance available and from environmental impact to the rate of cost inflation. By setting out systematically what are the costs and benefits of possible actions, the advantages and disadvantages of different waste management strategies can clearly be seen. So too can the best solution to specific problems.

The use made of economic analysis as a basis for decision making can be very flexible. The costs and benefits to be taken into account may be confined to those that are represented by financial flows. Or they may include implicit values given to social costs and benefits such as the effect of pollution on the environment, hazards to health and amenity and the like. The criteria used for evaluating costs and benefits can also be adjusted to meet particular requirements, by, for example, setting special constraints on the costs that may be incurred or on the extent of different forms of environmental impact that is acceptable.

Within the limits set by such constraints, the guide to action given by economic analysis comes from the assessment of the total net cost or benefit that different decisions might produce. But this assessment differs in 2 important respects from a straightforward addition of costs and revenues as might be obtained from accounting records.

First, in his assessment, the accountant is interested in the use that a particular method of handling waste makes of resources, whether or not these resources have an actual cash cost. For example, land that is already owned by or that is given to a government authority is costless in cash terms. But it may well have valuable potential for use in other ways than as a site for landfill or a location for an incinerator or a sewage treatment works.

In this case, the value of the potential use that is foregone, the "opportunity cost" needs to be included in the total cost of the process. Hence a full economic costing incorporates a number of such imputed "opportunity costs" as well as all the actual cash costs to be incurred. This is so even when attention is restricted to financial as opposed to social costs and benefits.

Secondly, economic costing takes account of the fact that the use of money has a cost in terms of interest, whether this is actually paid or not. As a result, the cost of outlays in the future is less than the equivalent amounts in the present owing to the potential for earning interest in the meanwhile. The pattern of expenditure over time can thus be important in determining the true costs of alternative waste management strategies. As discussed below, some form of discounted cash flow (DCF) technique is the normal approach used to handle this problem.

THE COSTS AND BENEFITS OF WASTE MANAGEMENT

The first and most fundamental step in using economic analysis in waste management is to identify all the relevant costs and benefits that need to be taken into account in the particular decision being examined. These costs and benefits then need to be quantified as far as possible. We consider below some important aspects of this process and a number of the main problem areas.

What Aspects of Waste Management?

It is important to be clear at the outset precisely what is the area of waste management involved in the analysis. Is the concern solely with final disposal of the waste or with the whole process of waste handling from initial collection through to disposal? What possible intermediate stages of waste handling are involved?

As an aid to clarifying thought in this area, some form of flow diagram of the type shown in Fig. 1 is useful. In general terms, 4 main stages of waste handling can be identified; that is:

- initial collection from the point of arising;
- pre-treatment to make the waste more suitable for final disposal and/or to enable useful materials to be recovered;
- bulk transport from the point of pre-treatment to the place of final disposal;
- final disposal of the waste including the recovery of any useful content.

As Fig. 1 indicates, wastes may flow through a variety of channels from initial collection to final disposal. In most cases, it is possible to analyse the costs and benefits of each stage of waste handling separately. This provides the basis for a modular approach to the analysis, where the figure for different elements can be examined separately or combined together in various ways to produce an overall view of the costs and benefits of a number of alternative strategies. Of course, account must be taken of any interaction between the stages of waste handling.

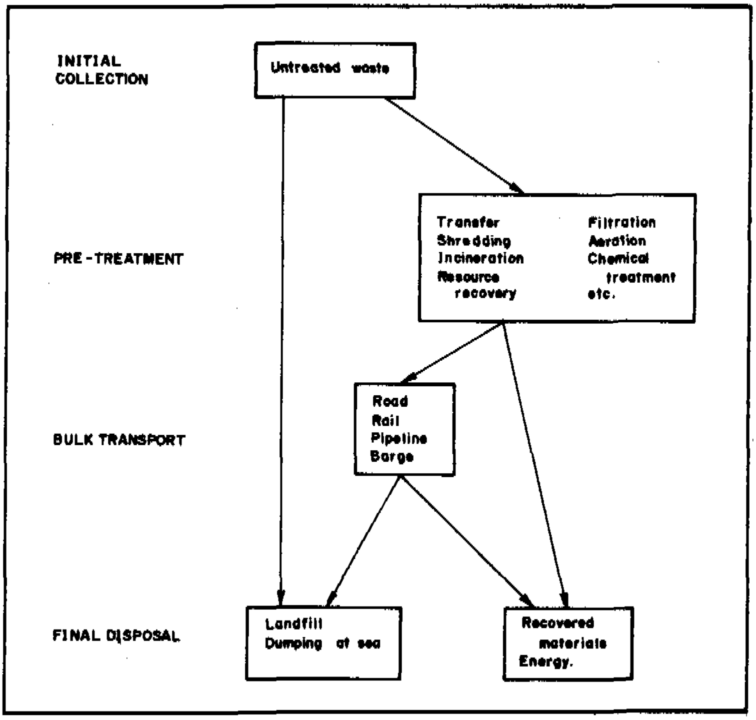
What Measures are Being Used?

As mentioned before, in considering costs and benefits, the economist is concerned with the use of resources in waste handling, not simply with actual cash flows. For the narrower analysis of financial costs and benefits, the resources of relevance can be grouped under 4 main headings:

- capital items: land; plant and equipment;
- operating items: labour; materials.

If social costs and benefits are also brought into account, additional use of the resources of land, air and water as a result of waste discharges must be covered as well as the effect of such discharges on amenity and personal health and safety.

In Table 1, listed in more detail are the types of costs and benefits that will normally need to be analysed under each of the main resource categories. Figures will be required for each of the stages of waste handling covered in the analysis, though naturally



The path of the arrows indicate the alternative ways in which waste can flow from initial collection through to final disposal.

Fig. 1 The Stages of Waste Handling

not every type of cost or benefit will be relevant at each stage. It should be noted that at this point in the analysis no mention is made of interest costs or the cost of capital repayment, since these do not represent a use of actual resources. Financing questions are considered below in the context of methods of evaluation.

Are the Correct Figures for Costs and Benefits Available?

Once the relevant categories of costs and benefits have been identified, they need as far as possible to be quantified. Two particular problems tend to arise here. First, there may be no figures available for certain items; this is, of course, almost certainly the case for social costs and benefits, but it may also apply to financial flows as well. Secondly, the figures that are available may not represent the correct values that should be attributed to the use of the resources.

Table 1. Possible Costs and Benefits of Waste Management

1. FINANCIAL COSTS

Land	- site acquisition - site preparation - site services (water, power etc.)
Plant and Equipment	- wages - operating plant - other handling equipment - vehicles
Labour	- wages - insurance and similar items - pension provisions
Material	- repairs and maintenance - fuel and power - water - chemicals etc.
Other	- plant insurance - administration and other overheads

2. FINANCIAL BENEFITS

Recovered materials and energy

3. SOCIAL COSTS AND BENEFITS

Impact of waste management on	- natural environment (land, water, air) - amenity - personal health and safety.

The description "financial" costs and benefits covers those items where there are normally financial flows corresponding to the items in question. The value of such flows of relevance for economic analysis may not be the actual cash payments or receipts (see text).

The problem of imputing values for different kinds of environmental impact and other social costs and benefits has been a subject of much discussion and controversy and will not be examined in detail here. But 2 points are perhaps worth making. Difficulties in arriving at an acceptable set of values for social costs and benefits often puts a severe limitation on the extent to which a formal analysis of these items is possible. However, it must always be remembered that the inability to carry out such an analysis does not mean that social costs and benefits can be or are ignored in waste management decisions; the ultimate decision will involve putting at least an implicit value on social impacts.

It is often not realised that the apparently more straightforward costs and benefits (such as spending on new plant, or revenues from the sale of recovered materials) have also to be estimated when making management decisions. By definition, any figures relating to newly constructed facilities must be estimated, and it is seldom that new facilities are sufficiently similar to those in existence for the latter to provide a precise model.

Thus most figures for capital or operating costs or for potential revenues will need to contain an allowance for contingencies. Furthermore, estimates of costs in the future must allow for the prospective inflation in costs from current levels as a result of increased wages and salaries, higher material prices, and the like. This can be a source of much uncertainty in the analysis; as discussed below, the allowance for inflation is of particular importance when comparing capital-intensive alternatives with those where a high proportion of costs are for labour and for materials.

Even where estimated costs and benefits are available, the values attributed may not be the correct ones for the purpose of economic analysis. This is because the figures most likely to be available are those for expected cash payments and receipts; these may not correspond to the opportunity cost of the use of the resources in question which is the value that the economist requires.

The example of the site cost for land was given earlier. Another important instance is in the case of labour costs. In economic terms, the use of labour that would otherwise be unemployed to work on waste handling projects involves an opportunity cost substantially below the actual wages and other costs paid. There may also be further gains since the increased employment may result in a higher level of economic activity and spending and these should be taken into account in assessing the total net cost or benefit from different types of waste handling.

METHODS OF EVALUATION

In most waste management decisions, the costs and benefits attached to alternative courses of action will arise at varying points of time. Where a new handling facility is being established there may be large capital costs to be incurred immediately followed by a regular flow of operating outlays and possibly revenues over the lifetime of the plant. When the question of tightening standards of pollution control is at issue, both costs and potential benefits will arise over a considerable number of years.

Thus it is seldom possible to evaluate the total costs and benefits of the alternatives by means of a simple process of addition. Normally it will be necessary to use some form of DCF technique to bring present and future figures on to a comparable basis. The most common approach is to calculate the net present value of the future flows, though internal rates of returns for different projects may also be applied where this technique is suitable.

In practice, a more simplified approach is quite frequently used. This involves annualising capital costs and adding thereto figures for annual operating costs to give the total net annual costs of projects. One advantage is that the resulting figures can be expressed per unit of waste being handled, a presentation that is often more readily understood than figures for net present value. A major disadvantage is that the resulting figures only correctly represent annual costs if there is no change in annual operating costs during the life of the project; the method thus ignores, in particular, the effect of future inflation.

The last problem can in part be overcome through the choice of interest rate for the purpose of annualisation. Careful consideration of what is the correct interest rate to use in evaluating costs and benefits is of great importance. Here again, the approach of the economist is that the rate should represent the opportunity cost of the use of capital to the investing authority. This may well not be the same as the actual interest cost to be paid on borrowings, though the latter is often used for practical convenience. Where social costs and benefits are being evaluated as well, more fundamental issues concerning the social rate of time preference need to be taken into account.

If the correct allowance for future inflation poses a special problem in the analysis, it is possible to carry out the evaluation using a rate of interest from which the implicit allowance for inflation, contained in market interest rates, has been excluded. This approach can, for example, be employed when annualised costs are being calculated. The implicit assumption underlying the use of such a "real" rate of interest is that future inflation will affect all types of costs and benefits equally.

If this is not likely to be generally the case, then this approach to evaluation should naturally not be adopted.

There are a variety of other techniques that may be applied in conjunction with DCF to assist in the evaluation of costs and benefits in waste management. Some have to do with the question of sensitivity analysis discussed below. Of the others, one of the most helpful is the use of linear programming to assist in decisions about the optimum location of waste handling facilites. This technique has been extensively used in practice in connection with the collection and disposal of solid wastes; with a carefully designed model of costs, it can handle actual operating decisions in addition to more general strategic problems.

SENSITIVITY OF THE RESULTS

The third, and equally important step in the economic analysis of waste management decisions, is the assessment of how far the conclusions reached from the initial evaluation of costs and benefits are sensitive to alternative assumptions about key elements in the analysis. These alternative assumptions may relate to the general environment within which the waste handling takes place, concerning, for example, the rate of inflation or the level of interest rates. Or they may affect matters more specific to waste management, such as the distance which the waste must be carried prior to treatment or disposal or the level of capacity at which particular handling facilities are operated.

Sensitivity analyses are of special importance where the decision being examined concerns the choice between alternatives of rather different character, for example between capital-intensive and labour-intensive methods of waste handling or if the balance between social and financial costs and benefits varies greatly. Listed below are some of the assumptions for which sensitivity analyses are frequently required in waste management decisions, with comments on the types of decision that they most affect.

Inflation and the Level of Interest Rates

All economic analyses used in waste management decisions will involve some assumptions about the level of interest rates and the expected rate of inflation and the latter is an area where there is normally a considerable degree of uncertainty about what is the correct assumption to make. The decisions particularly affected by varying assumptions are those where the alternative courses of action being examined have very different patterns of costs and benefits over time; for example where capital-intensive and labour-intensive projects are being compared, high levels of interest rates and/or low rates of inflation will put labour-intensive projects in a more favourable light, while low interest rates and/or high rates of inflation favour schemes with a large initial investment.

Levels of Plant Operation

Another set of assumptions of importance for the choice between projects that are capital-intensive and those that are not, is the assumed level of operating capacity of the plant and equipment. Naturally if expensive facilites are operated at well below their full capacity, as may well be the case in the initial stages of a project, the cost for handling a given amount of waste will be much greater than if a higher rate of operation is possible. It is important here that the ranges of operating rates assumed are realistic for the particular type of facility being examined and that they fully reflect actual operating conditions rather than what might theoretically be possible.

Transport of Waste

Many practical decisions about waste management involve consideration of how far it is worthwhile transporting the waste to gain other advantages such as economies of scale in disposal or treatment costs, or access to markets for recovered materials. Since most wastes are very costly to move any distance, the assumptions made about the likely distances involved in alternative handling plans are very important. Where transport is by road, care must be taken when assuming vehicle speeds, since these can be greatly influenced by the specific area within which the movement of waste takes place.

Imputed Values

All decisions for which a large proportion of the values for identified costs and benefits need to be imputed, will of course be very sensitive to the precise assumptions that underlie these values. This is especially the case where social considerations of environmental impact and the like loom large in the analysis. Since the latter is generally an area of much uncertainty and disagreement, it is vital that the conclusions of such analyses be fully explored with a variety of differently imputed values.

A PRACTICAL ILLUSTRATION

The remainder of this paper presents a practical illustration of how economic analysis has been used to assist waste management decision making. The illustration is taken from work that ERL has done on alternative methods of waste disposal in the United Kingdom. The figures quoted were orginally presented at a Public Enquiry into the possible use of an excavated quarry as a site for the controlled tipping of solid waste. They relate to the middle of 1977.

The Area Being Investigated

The decision being analysed was the strategic choice concerning methods of disposing of domestic solid waste. For this purpose, the disposal operation was defined to exclude the initial collection of the waste from the point of arising, that is the analysis covered the last 3 stages of waste handling identified in Fig. 1. Four main alternative methods of disposing of solid waste were considered. These were:

- direct tipping of waste at a landfill site;
- bulk transfer (with some compacting) and haulage of waste to landfill;
- pulverisation (shredding) of waste, followed by bulk haulage to landfill;
- incineration of waste with landfill of residual;

Basic Assumptions and Costs Identified

The analysis was concerned solely with financial costs and benefits and no allowance was made in the calculations for the varying environmental impacts of the different disposal alternatives. Since questions of overall strategy were being examined, the costs prepared were in the form of generalised estimates, based on the practical experience of a large number of waste disposal authorities. A modular approach to costing was adopted and separate figures were collected for each of the forms of pre-treatment involved, for the bulk haulage of solid waste by road and for final disposal by controlled tipping.

Cost figures were prepared for a waste handling operation capable of disposing 90,000 tonnes of solid waste a year over a period of 20 years, this being the constraint set by the size of the quarry whose use was being investigated. Some of the other main assumptions made for the calculations are given in Table 2 of particular note are the size of the plant required and its relation to the operating level assumed and the inclusion of revenue from reclamation for the incineration option.

Method of Evaluation and Resulting Costs

The simplified form of DCF calculation described above, that is combining annualised capital costs with an estimate of annual operating costs to give a total net annual figure, was used as a basis for evaluating the 4 options. An interest rate of 13 per cent was employed for amortisation; this figure was derived from the rates currently being paid by waste disposal authorities on loans of a life comparable to that of the project. The annual costs were expressed as an amount per tonne of waste handled to conform with practice normal in waste disposal costing in the United Kingdom.

The main figures of costs and revenues are summarised in Table 3. To assist in interpreting the table shows both the breakdown between the capital and operating elements in costs and the division between different stages of waste handling for each option.

Sensitivity Analyses

In this particular analysis, one of the most important assumptions concerned the distance over which the waste might have to be transported prior to tipping. The costs of transport over distances different from the 10 km assumed in the base calculations were calculated and the resulting effect on total costs of the 2 alternatives involving bulk haulage is illustrated in Fig. 2. In the figure, 2 sets of costs are given for incineration; the total cost, and the operating cost alone, since one option open to waste disposal authorities was that existing incinerator plant might be closed in favour of a policy of disposing of waste by bulk transfer to landfill if there was a potential saving in costs.

Table 2. Main Assumptions Used in Cost Calculations

	Method of Waste Handling			
	Direct Tipping	Bulk Transfer	Transfer with Pulverising	Incinerating
PLANT CAPACITY AND COST(ii)				
Design capacity Tonnes/Hour	(i)	50	50	25
Cost per tonne/hour of capacity	(i)	11,500	35,000	250,000
Operating hours p.a.	2,080	2,080	2,080	4,160
Waste handled p.a.	90,000	90,000	90,000	90,000
MANPOWER				
Staff employed	5	6	12	24
Average costs p.a.	4,500	5,000	5,000	5,500
POWER				
Requirement Kwh/tonne	(i)	5	20	31.25
Cost ¢/Kwh		1.88	1.88	1.88
OTHER OPERATING ITEMS				
Maintenance) % of	(i)	2½	2½	2½
Overhead) capital cost	(i)	½	½	½
RECLAMATION				
Ferrous metal % of imput tonnage	n/a	n/a	n/a	6.25
Value ¢ per tonne of metal				10.00

<u>Notes</u>: (i) Tipping costs have been calculated on the following assumptions:

space required for 1 tonne of waste = 1 m^3 (incl. cover)
capital cost per m^3 of space = 70 pence
power, maintenance & other running costs = 50 pence per tonne of waste
overheads = 25 pence per tonne of waste

(ii) All plant costs are amortised over 20 years: vehicles are amortised over 5 years.

Table 3. Estimated Current Costs of Waste Disposal(i)

	Cost £ per tonne of waste handling				
	Capital(i) Cost	Operating Cost	Total Gross Cost	Revenue	Net Cost
Direct Tipping	1.99	1.16(iv)	3.15	-	3.15
Bulk transfer to tip (10 miles, one way)					
Transfer	0.91	0.62	1.53	-	1.53
Bulk transport			1.28	-	1.28
Tipping			3.15	-	3.15
Total			5.96	-	5.96
Transfer with Pulverising (10 miles, one way)					
Transfer and Pulverising	2.77	1.62	4.39	-	4.39
Bulk transport(ii)			1.28		1.28
Tipping(ii)			3.15	-	3.15
Total			8.82	-	8.82
Incinerating					
Incinerating	9.89	4.13	14.02	0.63	13.39
Tipping of residual (iii)			1.05	-	1.05
Total			15.07		14.44

Notes:
(i) Costs relate to plant and/or tipping operation with a life of 20 years, handling 90,000 tonnes of waste a year. Capital costs have been amortised at 13 per cent.
(ii) No allowance has been made for possible economies from transfer and tipping of pulverised waste (see text).
(iii) Assumes that incineration reduces the tonnage of waste to be tipped by two-thirds.
(iv) Includes allowance for capital cost of site vehicles.

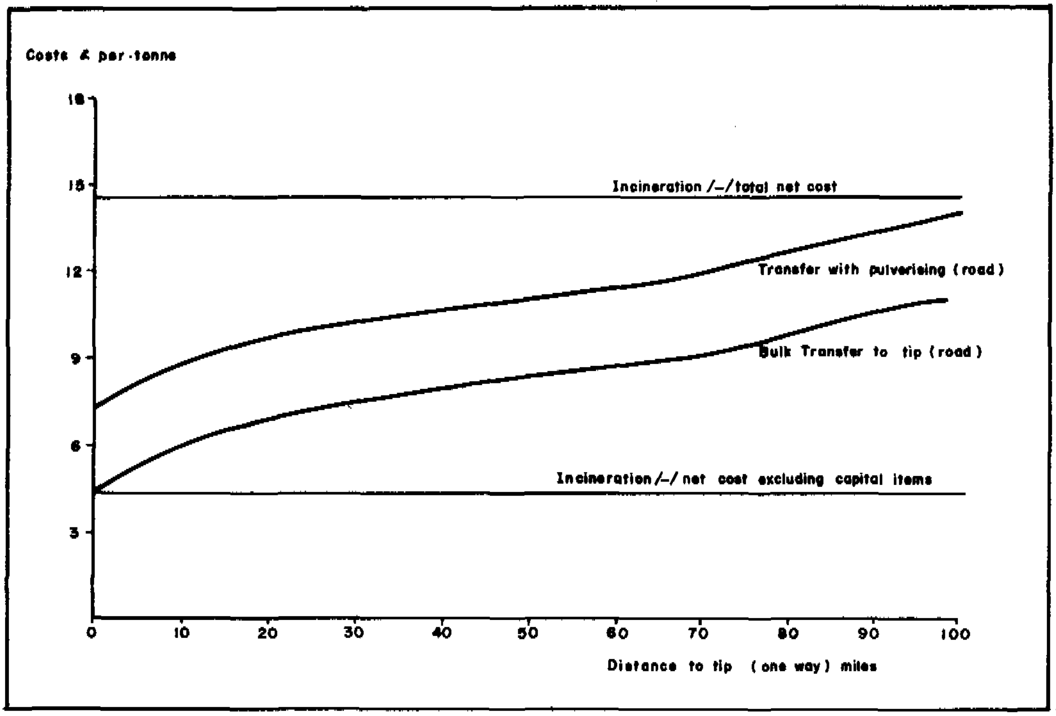


Fig. 2. Comparison of Estimated Cost of Waste Disposal

Other especially sensitive areas for this analysis were the operating rates for incinerator plant and the prospective rates of inflation. Both were examined, the latter by using a "real" rate of interest of 5 per cent as a basis for amortisation, thus implicitly assuming an average inflation rate of 5 per cent over the next 20 years.

Main Findings

The conclusions reached from this analysis were summarised as follows:

- direct tipping of solid waste is a cheaper method of disposal than either bulk transfer of waste to landfill, with or without pulverising, or incinerating;
- bulk transfer of waste, with some compacting but without pulverising, is estimated to be cheaper than the total outlay required for incinerating for distances to tip up to 100 miles (160 km) or more;
- but, even for short distances to tip, bulk transfer costs are likely on average to exceed the net operating cost (excluding capital items) of an existing incinerator;

- bulk transfer with pulverising is generally more expensive than transfer without this form of pre-treatment unless it enables sites much closer to the transfer station to be used.

These conclusions are based on experience in the United Kingdom and do not necessarily apply in other countries.

CONCLUSION

The example given above is but one of many possible illustrations of the way economic analysis can be used to assist those responsible for waste management. The value of economic analysis is not only that it gives a guide to the best course of action by calculating the net costs or benefits of the different options available. Equally important is the fact that economic analysis provides a logical framework within which waste management problems can be examined. It shows clearly the significance of the different elements in waste management and so helps to enlarge understanding of the key issues and problems in this important area.

ORGANISATION AND MANAGEMENT: A REVIEW OF ADMINISTRATIVE ASPECTS OF WASTE MANAGEMENT

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INTRODUCTION

Every day of every year wastes are produced that need to be collected, transported and disposed of efficiently, economically and with the minimum of environmental hazard.

If a waste treatment and disposal operation is to work, good management is required; yet consultants see many instances where expensive hardware has been procured but is lying idle and frequently in an unusable condition because inadequate thought and effort has been paid to the associated management and training requirements.

Some of these questions are discussed here, however it is particularly difficult to generalise on the question of administration. Each country will have its own approach which will have developed to meet the particular geographical and cultural needs. This paper therefore attempts to concentrate more on the issues and the needs rather than on laying down detailed proposals.

CO-ORDINATION

The Need for Co-ordination

There are often a large number of organisations, both governmental and private, who are concerned with waste: either as producers, handlers (collection, disposal etc.) or recoverers.

These are likely to include:

- Private householders: responsible for domestic wastes;
- Shops and offices: responsible for trade wastes;
- Manufacturing industry: which may be producers of hazardous wastes (e.g. some chemical manufacturers), recoverable wastes or relatively inert, non-recoverable wastes;

- Agriculture: this causes a problem particularly where there is intensive farming, where animals are kept in the urban areas or where (as in Hong Kong) animal wastes are dumped into water courses and an alternative means of disposal is therefore required;
- Construction and demolition: these wastes are of particular interest because they often can be used at the disposal sites for cover material and provision of access roads.

There are then the organisations responsible for waste collection and transport:

- The waste collection authority or authorities: In some cases collection and disposal have historically developed separately and in this case the collection authorities are separate from those responsible for treatment and final disposal;
- Private contractors: In most countries a large proportion of the commercial and industrial waste is handled by the companies themselves or by private waste haulage contractors. This may be no more than a man and a truck.

There are also the organisations with an interest in disposal:

- The disposal authority itself which is responsible for the location and operation of treatment and disposal plants;
- Other organisations who own sites suitable for landfill or own and operate private landfill sites;
- Organisations (public or private) which may dispose of waste in other ways; for example, dumping at sea.

In addition to these organisations which have a specific interest in waste and waste management there are the environment and other agencies whose activities are relevant. These include the following:

Air Pollution Control Agency: The agency responsible for air pollution will have an interest in the siting and emissions from any new incinerators.

Water and effluent control: The water supply and water pollution control agencies (which may nor may not be separate) will be concerned to ensure that landfill sites do not affect water supply or unduly pollute other water courses.

Planning Authorities: Land use planners are able to provide a guide as to areas where development is expected and they should be able to indicate land that might prove useful for transfer, landfill etc.

Energy and natural resources: There has been increasing interest in the potential extraction of energy or materials from waste; the relevant agencies are likely to wish to be kept informed of recovery proposals.

Residential and industrial development: New developments need to be catered for in any waste management plan and it is important that the waste planners are kept informed about all proposed new development.

Health Departments: The Health Authorities have a direct interest in collection and disposal methods, siting of facilities etc., in so far as they are likely to have an affect on public health.

Secondly, from the review of resource recovery policy it will be evident that if one of the options being given serious consideration is resource recovery, then it is important to involve the potential users of the recovered materials, energy or compost. Their involvement is required firstly to ensure that the end product is recovered in a form that can be most easily and economically used and, secondly, to ensure that long-term markets for the product are guaranteed.

The above list is far from comprehensive, but it does provide an indication of the wide variety of organisations and possible interests involved in waste management. The reasons why co-ordination is important may be summarised as follows.

Identification of landfill sites: There are likely to be a number of agencies interested in the siting of new disposal sites. These may include the water supply and effluent control agency, the planning agencies, the transport department, the environmental and health agencies, community action groups as well as the collection and disposal authorities. If all of these agencies can be made aware of the problems involved then there is a greater chance that sites can be identified with the minimum of disagreement.

Efficient use of landfill sites: Particularly where the available landfill sites are owned by more than one organisation, it is useful if agreement can be reached on the most effective way of using the available capacity. This will take account of other treatment and disposal facilities in the area and the types of waste: for example, if there is a particular site from which pollution risk is minimal, this should be used for the disposal of potentially hazardous wastes rather than for inert wastes such as builders' rubble. Similarly if capacity is scarce then builders' wastes are better diverted to other land reclamation schemes.

Forward planning: It is valuable to know well in advance of proposed housing and industrial development. There are 2 reasons. Firstly, it is obviously of assistance in planning future resource requirements. Secondly, at a more detailed but no less important level, it enables the authority to check that adequate storage and access facilities have been made available.

Integration of effort: This is particularly important where the collection, disposal and environmental authorities are from different agencies. We are aware that some waste authorities gain the impression that if the regulatory authorities have their way they would prohibit the disposal of wastes in any way at all. Secondly, and more seriously, environmental regulations (e.g. effluent control) often leads to an increase in the amount of solid or semi-solid wastes requiring disposal; the waste management authority needs to be aware of such intentions and plan for the necessary facilities.

ORGANISATION

Depending on the existing organisation, co-ordination is likely to be achieved through the establishment of a number of consultative groups or committees.

Waste Management Planning

This group should be constituted of agencies and organisations who can help provide the information that the waste management authority needs for its future planning and also to provide some 'feed-back' on the waste management authorities' proposals.

It is likely to comprise not only the collection and disposal authorities but environmental control agencies, industry and community representatives, agricultural interests (where relevant), town planners and industrial development agencies etc.

The principal functions are likely to include:

- Reviewing the existing and projected waste arisings in relation to the available collection and disposal capacity;

- To review any proposed regulations regarding collection, disposal or recovery;

- To review and provide advice on the waste management plan.

Identification of Sites

This group may be a sub-group of the first one, but it is also likely to include the water authority and representative from districts likely to be affected. Its principal function will be to discuss proposals for new sites and make recommendations on those that appear suitable. It should also be responsible for reviewing any complaints about the operation and affects of existing sites.

Resource Recovery

As has already been noted above, an integral part of any scheme to increase the amount of waste recovered is to ensure that the activities of the suppliers (residents, collecting agencies, private contractors etc.) are integrated with, and that the suppliers are aware of, the needs of the potential users of the material.

MANAGEMENT

Little attention tends to be paid to the internal management and operation of collection and disposal agencies. A great deal of attention is paid, on the other hand, to the purchase of a new incinerator: but the work of the agencies themselves (where the potential saving may be enormous) is ignored.

Yet again it should be stressed that no amount of hardware or even forward planning will in itself shift the waste, but only every day collection and disposal. This is highly labour-intensive and to be conducted efficiently requires a high level of man management.

Once again it is difficult to generalise. But in examining the efficiency of the operations there are a number of points that need to be covered.

Training

Adequate training of all levels of staff may appear to be a self-evident requirement. But it is important that all levels of management down to foreman level should be trained in management as well as technical skills. This should include all aspects of man management (setting of objectives, review of progress etc.) and also reporting procedures. This and technical training may best be handled through the seminar approach (involving the participants) rather than through a series of lectures. In this way the courses can take account of the day to day problems and also act as a means of communication.

Communication

Everyone in the collection and disposal organisation should be at least aware of the plans and objectives of the waste management authority and how these are likely to affect them now and in the future.

Management Control

Internal systems should be established to enable the senior officials of the relevant agencies monitor performance and efficiency. At a more basic level, there should be controls that enable senior management to check whether each man being paid for a specific job is actually carrying out the job (or, indeed, exists at all).

Financial Control

Waste management often forms one of the largest items in a local public authority's budget of recurring expenditure. Guidelines should be laid down:

- On capital expenditure: expenditure on all major items should obviously have the independent approval of the most senior financial officer in the "system" (he may be in the local authority or in the ministry);

- Recurring expenditure for equipment: the major expenditure is likely to be on vehicle and other equipment operating expenses (fuel, spares, repairs etc.); it is important that guidelines should ensure that no one supplier is particularly favoured and that no individual officer is solely responsible for selecting a supplier;

- Manpower costs: as noted above, there should be a system to ensure that no payments are made unless there is evidence that the individual has turned up for work. Once again, this might appear not a little obvious; but in a large labour intensive organisation where some casual, unskilled labour is also employed the opportunities for malpractice are considerable.

REGULATORY REQUIREMENTS

Waste management operation will require the support of appropriate regulations and legal controls. These may be embodied in new legislation or scheduled as regulations under existing laws. The decision on this and the drafting of the controls themselves will of course be a matter for the lawyers.

However, it will be up to the waste management authority to make the necessary proposals. Development of such proposals should take account of the following:

Practicality

Regulations that cannot be complied with or which are difficult to comply with are likely to rapidly fall into disuse. For example:

- It is not reasonable to require a householder to bring his waste to the nearest collection point unless the authority plans to provide collection points not more than a short walk from every dwelling;

- Alternative disposal facilities will be required if the regulations prohibit industry from dumping its waste at the authority's disposal sites: otherwise this will simply promote illegal dumping;

- Schemes requiring the notification of every load of waste transported by private waste haulage contractors may, from a control and planning point of view, appear attractive, but the authority may find the handling of say 100,000 pieces of paper a year will strain its resources.

Enforcement

The enforcement is an important factor that should be taken into account in the framing of new regulations; obviously it is preferable:

- Firstly, that existing law enforcement bodies such as the police should not be required to enforce the regulations except where there is no practical alternative since solid waste management is likely to form a relatively low priority in their work;

- Secondly, that wherever possible, the regulations should be 'tacked-on' to existing systems: for example, in Sweden illegal dumping of abandoned vehicles is controlled through an additional payment made at the time of first licensing the vehicle, which is refunded to the final owner when he takes the old vehicle to an approved scrap yard.

Economic Implications

New regulations may have an impact on the costs to government as well as to manufacturing industry. Apart from the cost of enforcement, government itself is often a waste producer and controls may considerably add to its costs.

Environmental Implications

Any proposed new waste management regulations should clearly be discussed with them, other regulatory agencies.

Where Regulations May be Needed

The areas in which regulations may be required include the following:

- It may be necessary to define different categories of waste in order to control the way they are transported or controlled.

- Regulations governing the way that wastes are stored in domestic, trade or industrial premises may assist the collecting authority. This may be tackled through planning controls or building regulations.

- It may prove necessary to license waste transporters to ensure at least minimum standards regarding types of vehicle, procedures, etc. and to provide some sanction against illegal dumping by such operators.

- The problem of litter and illegal dumping tends to be more one of enforcement than enacting regulations; this is as much a matter of public education and, to the extent possible, exercising controls over the product itself - for example the EPA in the United States has proposed that all containers sold on federal premises should be returnable: this approach may be adopted at beaches and other locations where litter is a particular problem;

- Effective Resource Recovery Regulations can, in some cases, for example waste lubricating oil, have an environmental as well as a resource benefit.

OPTIONS FOR RESOURCE RECOVERY FROM SOLID WASTE

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INTRODUCTION

It is readily apparent that the absolute costs of waste management are governed very much by the environmental standards we set. There are also various processing methods for treating and/or recovering useful products from solid wastes which, given the environmental standards aimed for and the constraints imposed by local circumstances, require economic comparison before any decision on waste handling can be taken.

In other words, it is these comparisons that will primarily influence the choice of a waste disposal strategy that achieves the required standards at the least cost and with the optimum use of scarce resources. Here is an outline of the main options for achieving recovery of valuable resources from solid wastes and an examination of some of the key criteria which are usually used to determine whether resource recovery from waste might be worthwhile.

Reclamation from waste is, of course, not a new idea, either in developed or developing countries, for man has always attempted to reclaim waste in many diverse ways, whenever it seemed attractive to do so. However, recovery from waste attracted a growing interest during the past 2 decades or so, particularly from governments, and although there are probably many reasons why this has happened, 2 of the main influencing factors are certainly:

- The continuing growth in the generation of wastes, the disposal of which poses management and environmental problems, particularly in urban areas.

- A growing awareness that primary or virgin resources are in many cases in finite supply, coupled with recent, sharp increases in the price of energy and some other natural resources.

In spite of this growth in interest in resource recovery, as manifested in intensive research and development into recovery from waste and substantial expenditure on test and demonstration plants in many developed countries, there remain very large quantities of solid waste which are disposed of with little or no recovery attempted. There are many reasons why this is so, for instance:

- Natural resources occur in concentrated form. Wastes are dispersed and collection and transport costs are high.

- Virgin materials, even unprocessed, tend to be more homogeneous in composition than wastes. Sorting and upgrading of mixed wastes is costly.

- Virgin materials are usually of higher quality than wastes and less heavily contaminated. Product specifications and quality are therefore easier to control.

- Plant locations and process technologies exist and were developed to use natural resources. Waste processing requires different technologies and different plant locations.

- Synthetic hydrocarbon materials used in combination with natural materials make economic sorting and recovery difficult for both.

Virtually all of the opportunities for easy and profitable recovery are already being exploited, e.g. process scrap from iron and steel manufacture, waste paper from paper conversion, etc.

In these cases, there is a clear economic incentive to recover materials, where these are available in a pre-separated, concentrated and relatively uncontaminated form, and where the materials has a high inherent value and costs of collection and processing are comparatively low.

The position is very different in the case of potentially mixed wastes which make up most of the solid waste currently disposed of without any recovery. It is these types of solid waste, e.g. household refuse, mixed industrial refuse, demolition waste, sewage sludge, which are of major concern to the waste management planner and on which prospects for increasing the amounts of waste recovered must largely be founded.

The main options presently available for recovering useful products from potentially mixed solid waste therefore form the essential subject matter of what follows.

REVIEW OF METHODS FOR TREATING AND RECOVERING USEFUL PRODUCTS FROM POTENTIALLY MIXED SOLID WASTE

The reason for including the notion of treatment in the above heading is that treating the waste is almost always a prerequisite for efficient recovery of products from waste, though not all forms of waste treatment are aimed at resource recovery. In practice, it is difficult to draw a hard and fast distinction between waste treatment for recovery and waste treatment for disposal, for both objectives are often achieved simultaneously.

For instance, incineration, with recovery of the heat generated, converts (and thus effectively destroys) a substantial proportion of the waste feed, releasing heat which may then be applied for a variety of purposes. However, there remains a comparatively inert residue, amounting to about 10 per cent by volume or about 40 per cent by weight of the original refuse feed, which must usually be landfilled unless an opportunity exists nearby for long-term utilisation. Hence, some part of the waste is to all intents and purposes disposed of by incineration, while at the same time a potentially valuable resource (energy) is recovered.

Even conventional sanitary landfill, which is often thought of solely as a means of disposal, can serve a potentially useful purpose in reclaiming derelict land.

Certain kinds of mixed solid waste, e.g. demolition waste, industrial slags, by their nature offer only a limited potential for materials recovery, and so the vast bulk of such wastes can only be landfilled.

Conventional methods for treating and disposing of most mixed solid wastes may be generally summarised as follows:

- Landfilling (with or without various forms of pre-treatment, and with varying degrees of site control;
- incineration (with or without heat recovery, and with possible recovery of ferrous metals and residual slag);
- composting (with varying degrees of pre-treatment and product refinement, with or without ferrous metals recovery).

The less conventional methods being developed or under consideration for recovering valuable materials and/or energy from potentially mixed waste can be broadly divided into:

- Separate collection systems in which specified materials are separated from other wastes by the originator of the waste, and are collected by a municipal or commercial organisation;

- centralised mixed waste recovery systems, in which mixed waste is delivered to a centralised plant, where it is mechanically, thermally, chemically or biologically processed to produce various valuable materials or energy.

This broad definition is presented conceptually in Fig. 1.

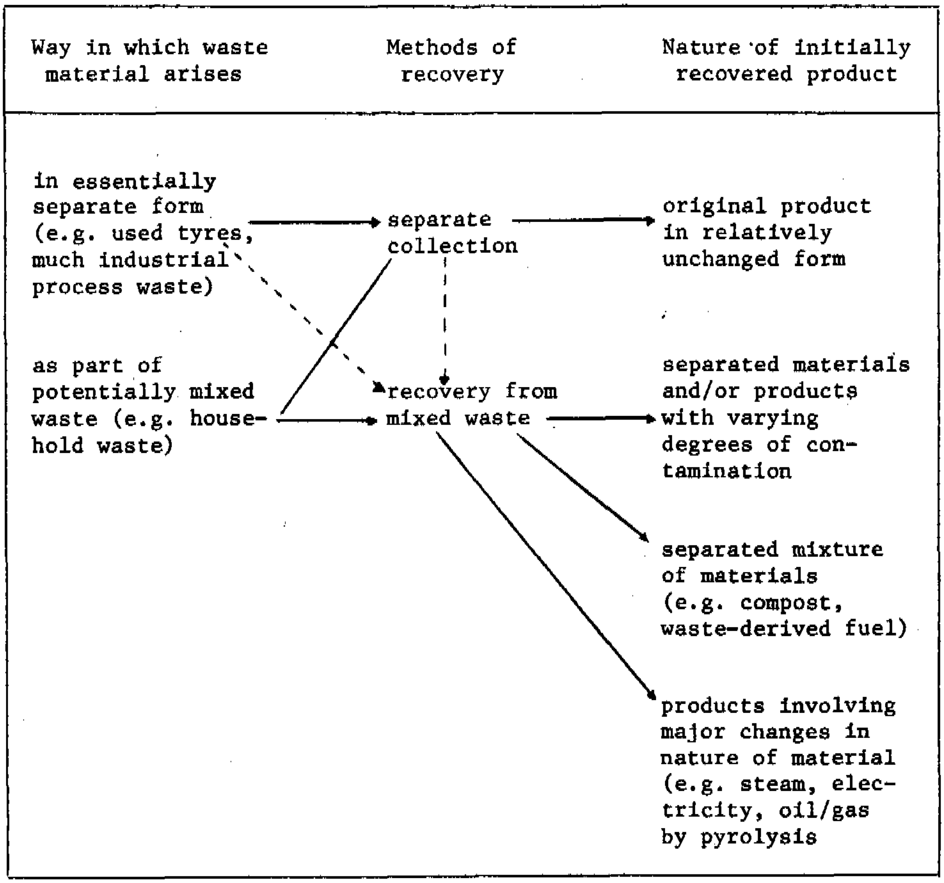

Fig. 1 Initial Recovery Methods and Nature of Initially Recovered Product

Mixed waste recovery systems can be further sub-divided as follows:

- Recovery centres: centralised stations to which the originator brings his waste, generally in a pre-separated form.

- Materials recovery processes in which mechanical systems are applied to extract useful or valuable materials from the waste.

- Solid fuel recovery processes which extract a solid fuel which may be used as a substitute for conventional fossil fuel in an existing process (refuse-derived fuel).

- Pyrolysis processes which thermally convert the waste into combustible gases or oil, useful chemicals and slag.

- Composting processes in combination with one or the above systems.

- Chemical and other biological processes which convert waste into, for example, alcohol, methane or other chemical products.

Incineration

Incineration is a well-established and comparatively reliable method of treating many mixed wastes prior to disposal. This status is demonstrated in the fact that there are now some 200 incineration plants in operation in Western Europe for household and similar kinds of waste. This method of treatment also affords the recovery of part of the energy content of the waste, which may be applied for a variety of purposes, e.g. power generation, district and/or process heating, water distillation.

A part of the energy so recovered can also be used for different functions within the plant itself. However, incinerator technology has as its prime aim, the substantial reduction in volume of the waste to produce a virtually inert residue. The recovery of heat (and frequently the recovery of ferrous metals and the residual slag as well) are usually secondary activities which can provide a useful credit for offsetting against the operating costs of the plant.

Despite technological developments, which have led to higher thermal efficiencies (e.g. combined heat distribution and power generation) incineration remains a relatively inefficient method of recovering the energy value in waste. Moreover, it is often difficult to guarantee supplies of energy from an incineration plant and balancing heat production and demand can be problematic.

Incineration, with or without heat recovery, is the most expensive form of conventional solid waste treatment, due largely to the very high capital costs involved in building a plant. This is particularly the case with plants having a small capacity, or where refuse throughput falls consistently short of design capacity.

The scale effects which characterise incineration plants and the need to maintain throughput at a consistently high level, in order to avoid prohibitively high operating costs, are major drawbacks of this type of plant and make this a somewhat inflexible method of treatment in areas with modest arisings of suitable waste. Incineration has found greatest success in large urban areas generating substantial quantities of waste.

From an environmental point of view, incineration leads to drastic reductions in the volume of the waste (up to 90 per cent) and the resulting residue is rendered largely inert and is, therfore, ideal for landfilling or, alternatively, for use as a fill material in the construction industry. However, incineration of waste gives rise to a number of atmospheric emissions which normally would have to be removed to prevent serious environmental impacts occurring. The technology for achieving this is available, but adds substantially to the capital costs of an incineration plant.

Composting

Composting is likewise a traditionally-established process of treating household refuse and similar wastes in Europe. Stated simply, composting is primarily a biological process whereby micro-organisms feed on and convert the organic components of the refuse, and produce a humus-like material which can then be used in several ways, e.g. as a soil improving agent, as a bulk material for land reclamation operations, as a cover material for landfilling operations.

In practice, composting involves a series of overlapping process stages which are biologically and chemically very complex. The process and the compost product are affected by a large number of determining factors, for example, composition of the waste, the form and extent of any pre-treatment of the waste, moisture content of the waste, the availability of oxygen or air, process pH and temperature, the carbon/ nitrogen ratio of the waste, etc.

Refuse composting may take the form of simple windrow-composting or much more complex composting, with extensive pre-treatment, extraction of metals and other biologically inert fractions, processing in various types of digestors, admixing of nutrient substances, etc.

One also has the possibility of composting refuse in combination with sewage sludge, which may be an important future consideration with the trend towards more extensive and more efficient sewage treatment in developing countries.

Simple composting of refuse in open windrows normally results in a very inferior quality compost product which is difficult to sell and, in some cases, cannot even be given away. In addition, this method of composting requires a relatively large plant site, an insensitive site location, while odour formation and site drainage can be problematic.

More complex composting which selects the more suitable fractions of the refuse for processing, gives rise to a better quality product but, at the same time, is much more expensive to operate and leads to a low compost yield and high arisings of residual matter. Problems of odour emissions and site drainage are not normally associated with mechanised composting plants.

Composting has, in the past, suffered considerably from problems connected with the marketing of the compost product. These problems are, to some extent, organisational in nature and stem from:

- A lack of information on potential customers for compost and their requirements;

- the lack of any quality standards for different compost products;

- the sensitivity of compost marketing to transport costs;

- doubts among potential users about the long-term effects of certain trace elements in the compost product.

This last problem is currently being extensively researched in the Federal Republic of Germany, and it would appear that any risk associated with trace elements in the compost can be eliminated by controlling the concentration of these elements during processing and by establishing a code of practice for using compost produced from refuse.

Composting as a process in its own right and can be considered an inefficient method of recovering certain of the valuable materials contained in refuse. Paradoxically, most of those refuse reactions with the highest material or energy value (wood and hardboard, rubber and plastics, textiles and metals) are the components which are either impossible or very difficult to compost, and must, therefore, be separated out, or are otherwise responsible for detracting from the quality of the compost product.

This, therefore, opens up the possibility of producing a high quality compost product at a comparatively lower cost if applied in combination with some form of material sorting and recovery process. This option is considered further below.

Separate Collection

Separate collections systems aim to reclaim valuable materials before they become part of a mixed waste stream. This obviates the need for later manual or mechanical separation from the mixed waste, and ensures that the reclaimed materials are relatively uncontaminated. This requires the segregation of the materials concerned from other wastes by the originator.

Many such schemes have recently been started in Western Europe by local authorities, by industrial groups and by voluntary organisations, often with co-operation. The materials reclaimed vary from scheme to scheme, the main ones being: peper, cardboard, plastics, glass and tin cans. Such schemes have been widely used for recovering valuable industrial wastes for many years.

The main advantage of separate collection as a method of initial recovery, is that a waste material can be recovered in a form which closely resembles that of the original product or raw material. Separate collection as a method of recovery is likely to be technically most suitable where:

- Wastes of different types arise in an essentially separate form (e.g. old newsprint);

- waste products are easily separated by their owners and are not seriously contaminated in use (e.g. glass bottles);

- a substantial amount of the waste arises at one point to make separation and collection worthwhile.

Referring to these technical conditions it will be appreciated that only certain kinds of post-consumer solid waste meet these conditions. There are also inherent limits on the extent to which a material can be separated out from consumer waste prior to collection. Many consumer goods contain closely mixed materials (e.g. laminated packaging) while some are heavily contaminated in use (e.g. food packaging).

In addition, the materials which may be most readily collected separately from households are generally of low density and available only in small quantities, which makes collection very expensive. Recent experience with such schemes around Europe has shown that 2 critical factors for the success of a scheme are:

- Gaining the sustained co-operation of householders;

- the existence of local markets for the reclaimed material.

The main advantages of using separate collection as a method of recovering domestic waste are that such schemes may be quickly put into effect and that a relatively small capital expenditure is required. Separate collection schemes can, in certain circumstances, prove to be a viable method of recovering certain types of waste, but that they do not constitute a long-term solution to the problem of treating and removing the bulk of mixed solid wastes.

Recovery Centres

A recovery centre is a facility that will receive, store and sometimes process specific wastes from domestic consumers and/or industry, for later use. Such centres can range from the simple skip placed temporarily in a supermarket, which seeks to recover small quantities of low value material, e.g. glass containers, to the large, permanent centre incorporating one or more processes for treating a variety of recovered materials. The main advantages of a recovery centre are:

- A recoverable material is prevented from entering a mixed or contaminated waste stream;
- the costs of delivery to the centre do not (normally) form part of the costs of recovery.

The viability of recovery centres is generally hindered by:

- The difficulty of maintaining a high level of public response;
- the low value of the wastes recovered; and,
- the problems of securing a stable market for the reclaimed materials.

Nevertheless, numerous schemes are currently in operation to provide simple collection points for glass containers, and sometimes tin cans and plastic containers. Where public response is forthcoming (and there is much evidence to show that it is), such simple collection points are preferable to trying to recover these types of material from mixed waste. As in the case of separate collection schemes, recovery centres can provide a useful contribution towards recovering certain post-consumer wastes, but do not represent a long-term solution for managing large quantities of solid waste.

A point worth mentioning in this regard, is that centralised mixed refuse recovery plants can also function as a collection point for receiving certain types of separated waste from the public.

Materials Recovery Processes

A variety of processes have been developed in Europe and the USA for physically removing useful or valuable materials from household and similar solid wastes. A summary of such processes either in operation or under development, is shown in Table 1.

The materials recovered vary from process to process, but typically products would include a fibre product consisting largely of paper, board and some textiles; ferrous metals and a mixed organic fraction consisting of vegetable and putrescible matter.

Further process steps (found particularly in the USA) aim to recover non-ferrous metals (predominantly aluminium) and glass (frequently colour sorted). The materials recovered by these processes a are, generally, of low grade and often need further treatment before they can be marketed.

While most of the individual items of equipment used in material sorting processes have been widely used for other purposes over many years, bringing these together to form an integrated materials recovery process can give rise to a large number of complex problems. All of these material sorting processes suffer to some extent from having to handle efficiently substantial fluctuations in the characteristics of the waste, principally composition, density and moisture content.

In principle, it is technically feasible to progressively refine the recovered products to a point where they become attractive to potential users. However, this can usually only be achieved by employing additional process steps, the costs of which often exceed the value added to the recovered material.

This is a major disadvantage of material recovery systems because:

- The initial sorting steps produce very low quality products, which are very difficult to sell at an economic price;

- further process steps can be added to upgrade the recovered products, but this leads to a more complicated and costly process layout which is frequently difficult to justify in terms of the marginal value added to the recovered product.

Moreover, as the process configuration becomes more complicated, more sophisticated process controls are required and the plant becomes more susceptible to breakdowns and to higher maintenance and energy costs. These, then, are the main problems which almost all of the processes shown in Table 1 have suffered from.

Mechanised material recovery systems are still under development, and much effort is currently being devoted towards improving the quality and yield of the recovered products while, at the same time, avoiding complex process configurations, with their associated high energy and maintenance costs.

The commercial viability of material recovery processes (as with any resource recovery system) is critically dependent on the income received from sale of the recovered products. In this respect, these processes are particularly vulnerable to the violent fluctuations which occur in the prices for low-grade waste paper, low-grade ferrous scrap and mixed waste plastics.

Table 1. Examples of Materials Recovery Processes Under Development or in Operation

Location	Key participants	Process	Output	Announced tonnage	Announced capital costs, $M	Status
Franklin, Ohio USA	City of Franklin, Black Clawson Co.	'Hydrasposal/Fibre-claim' wet pulping, magnetic separation, heavy media, jigging electrostatic precipitation, optical sorting	Fibre product, ferrous metals, aluminium, colour-sorted glass	2,000 tpd	73	Under construction; operational in 1978
New Orleans, USA	City of New Orleans, Waste Management Inc., NCRR Inc.	Shredding; air classification, magnetic and other mechanical separation; hand-sorting (paper)	Paper; ferrous metals, aluminium, glass	650 tpd	7.75	Shredding/landfilling operational; recovering ferrous and aluminium metals; glass recovery just started; paper recovery planned
Wilmington, Delaware, USA	Delaware Solid Waste Authority, EPA	Shredding; air classification; magnetic and other mechanical separation; froth flotation; aerobic digestion	Ferrous metals; non-ferrous metals; glass; compost; fibre or fuel product	1,000 tpd of refuse with 350 tpd of 20% solids digested sewage sludge	32 9 from EPA, remainder from the Authority	Negotiations under way with Raytheon Service Co. for full service contract which includes design, construction and operation
Warren Spring Laboratory, UK	WSL, Department of Environment	Refuse liberation, rotary scfeening, magnetic separation, air-classification, sink/float and ballistic separation, shredding	Paper-rich fraction, ferrous metals, low-grade fuel product, optional glass and non-ferrous metals recovery	4 tph pilot plant	Two full-scale (200 tpd) plants at approx. $4 million each	Two plants based on WSL process under construction at Doncaster and Tyne and Wear. Start-up 1979.

Table 1. (Continued)

Location	Key participants	Process	Output	Announced tonnage	Announced capital costs, $M	Status
Haarlem, Netherlands	Central Technical Institute TNO, Esmil-Habets	Magnetic separation; shredding; air classification; baling	Paper, plastics, ferrous metals	15 tph pilot plant	n.a.	Scale-up planned
Rome and Perugia, Italy	City of Rome, Sorain Cecchini	Magnetic separation; various forms of automated sorting; residue incineration	Paper, plastics, animal feed, ferrous metal, compost, steam	Two plants; 600 tpd 1,200 tpd		Operational
Munich, FRG	City of Munich Krauss-Maffei (System R-80)	Magnetic separation; shredding; air classification	Paper, ferrous metals, compost (potentially), glass (potentially)	5 tph pilot plant	No details	Being offered at throughputs of up to 20 tph
Aachen, FRG	RWTH, Aachen	Screening; magnetic separation; shredding; air classification; dense media sorting; optical sorting	Paper, ferrous metals, non-ferrous metals (theoretically), compost raw material, glass	1.5 tph pilot plant	Ca. $4m for 15 tph plant (estimated)	Scale-up planned by Firma Siebtechnik
Tübingen, FRG	Federal Government, Zweckverband Abfallverwertung Reutlingen/Tübinger Land Baden-Württemberg (privated participants yet to be decided	Not yet decided	Paper, ferrous metal, glass, compost, plastics (possibly RDF if paper recovery should not succeed)	300 tpd (first stage) 600 tpd (second stage)	Ca. $25m (estimated)	Planned
Högdalen, Sweden	Svenska Fläktfabriken AB	Shredding; screening; air classification, magnetic separation, froth flotation; drying	Paper, ferrous metal, plastics, glass (optional)	5 tph pilot plant	no details	Being offered at full-scale

Fuel Recovery Processes (Refuse-derived Fuel)

What may be viewed essentially as a variation on mechanised materials recovery processes, are those processes which recover a solid, potentially transportable (and to varying degrees storable) fuel from refuse. The primary aim of RDF processes is to separate the combustible fraction of refuse, and process these in a variety of ways to produce a fuel which may be substituted for other fossil fuels, particularly coal and lignite, and possibly heavy fuel oil. Some of the RDF processes which have been developed to date are shown in Table 2. The advantages of processing domestic refuse into RDF are primarily twofold:

- The separating efficiencies required of the process need not be so high as those for materials recovery processes, and hence the process configuration tends to be simpler and less energy consuming;

- if necessary, the fuel product may, within limits, be transported to distant consumers and used in commercial combustion facilities, which generally have a significantly higher thermal efficiency than refuse incineration plants.

Because RDF processes aim to recover the combustible fractions of the waste, they also extract a greater proportion of the waste than materials separation processes. Fuels produced from municipal solid waste contains much smaller quantity of sulphur than most conventional fossil fuels, which is a distinct advantage when trying to reduce emissions of sulphur oxides from combustion.

It has been suggested that the presence of PVC packaging materials in the fuel might be problematic in terms of emissions of chlorine compounds in the flue gas and might also conceivably lead to corrosion difficulties in the combustion plant itself. However, the use of PVC film for packaging is disappearing in Europe and most of the PVC found in household refuse is in the form of heavy gauge products which can be sorted out from the fuel fractions.

The first RDF process to be built and operated commenced operation in 1972 in St Louis, USA. This was a demonstration plant supported by the US Environmental Protection Agency in co-operation with the city and the Union Electric Company. The process itself was of a very simple design, and in the initial stages some operating difficulties were experienced with the firing of the fuel. These difficulties were subsequently eradicated by design modifications.

The fuel produced by the St Louis demonstration process was of a fairly crude nature, and later American RDF processes were generally of a far more complicated design and produced a highly refined fuel product. Later European RDF processes benefited considerably from the

Table 2. Examples of Refuse-Derived Fuel Processes Under Development or in Operation

Location	Key participants	Process	Output	Announced tonnage	Announced capital costs, $M	Status
Ames, Iowa, USA	City of Ames, Henningson, Durham and Richardson (Designer)	Paper baling; shredding; magnetic separation; air classification; screening; other mechanical separation	RDF (for use by utility), baled paper, ferrous metals, aluminium	200 tpd	7	Operational since 1975
Baltimore County, USA	Maryland Environmental Service, Baltimore County, Teledyne National	Shredding; air classification; magnetic separation	RDF; ferrous metals; aluminium; glass	600-1,500 tpd	9	Operational
Bridgeport, Conn., USA	Connecticut Resources Recovery Authority, Occidental Petroleum Corp., Combustion Equipment Associates.	Shredding; magnetic separation; air classification; froth flotation	RDF (Eco-Fuel II), ferrous metals, aluminium, glass	1,800 tpd	53	Under construction; operational 1978
Chicago, USA	City of Chicago, Ralph M. Parsons Co., Consoer, Townsend & Assoc.	Shredding; air classification, magnetic separation	RDF for use by utility, ferrous metal	1,000 tpd	19	In shakedown; full capacity during 1978
East Bridgewater, Mass., USA	City of Brockton and nearby towns, Combustion Equipment Associates.	Shredding; air classification, magnetic separation, other mechanical separation	RDF (Eco-Fuel II) for industrial boiler, ferrous metals	1,200 tpd	10-12	Operational

Table 2. (Continued)

Location	Key participants	Process	Output	Announced tonnage	Announced capital costs, $M	Status
Lane County, Oregon, USA	Lane County, Allis -Chalmers Corp., Western Waste Corp.	Shredding; air classification; magnetic separation.	RDF; ferrous metals	500 tpd	2.1 (at existing transfer station)	Operational
Milwaukee, USA	City of Milwaukee, Americology (American Can Co.), Bechtel Inc.	Shredding; air classification; magnetic and other mechanical separation.	RDF for use by utility; baled paper; ferrous metals; glass concentrate.	1,600 tpd	18	Partially operational
Monroe County, New York, USA	Monroe County, Raytheon Service Co.	Shredding; air classification; magnetic and other mechanical separation; froth flotation.	RDF for use by utility; ferrous metal; non-ferrous metal; mixed glass.	2,000 tpd	51 (includes cost of associated transfer station)	Start-up late 1978
Newark, New Jersey, USA.	City of Newark, Combustion Equipment Associates, Occidental Petroleum Corp.	Shredding; air classification; magnetic separation.	RDF (Eco-Fuel II) for use by utility; ferrous metal.	3,000 tpd	70 (including fuel user conversion costs)	Under construction; operational late 1979
Zürich, Switzerland.	Bühler & Co.	Shredding; air classification; magnetic separation.	Pelletised RDF; ferrous metal.	Pilot plant	na	Prototype plant (10 tyh) under construction at Eastbourne, U.K.; captial cost estimated at approx. $4million. Start-up late 1978.

Table 2. (Continued)

Location	Key participants	Process	Output	Announced tonnage	Announced capital costs, $M	Status
Birmingham, UK.	Imperial Metal Industries Ltd.	Shredding; magnetic separation.	Low-grade fuel product; ferrous metal.	200 tpd	0.5 (very simple plant)	Operational
Westbury, Wiltshire, U.K.	Associated Portland cement Manufacturers Ltd.	Shredding; magnetic separation; screening.	RDF for use in cement kilns; ferrous metal.	300 tpd	no details	Operational. Further plant at Shoreham, U.K., also operational
U.K.	The General Engineering Co. (Radcliffe) Ltd.	Rotary screening and homogenisation; admixing of oil sludges; magnetic separation; optional air classification; pelletisation.	RDF pellets; ferrous metal.	-	-	Experimental
Stockholm, Sweden.	The PLM Co.	Shredding; various forms of mechanical sorting; air classification (optional); magnetic separation; fuel densification; composting (optional).	RDF (densified); ferrous metal; compost (optional).	5 tph pilot plant	-	Operational
Herten, Federal Republic of Germany.	Siedlungsverband Ruhrkohlenbezirk, Gesellschaft für Materialrückgewinnung and Umweltschutz m.b.H.	Developed version of American 'Eco-Fuel II' process. (Plant will also include material sorting and incineration units)	RDF; ferrous metals.	n.a.	n.a.	Planned

American experience in that they aim ed to use comparatively simple process designs to produce a fuel of intermediate quality.

Most later processes also use methods for densifying the fuel, e.g. briquetting or pelletisation. Based on experience to date, RDF plants would appear to involve capital investment costs substantially lower than those for incineration plants, and noticeably lower costs than those for mechanised materials recovery plants.

Pricing of the RDF product is related to prevailing prices of the fossil fuel for which it is substituted (until now, only coal) and, hence, reflects a degree of price stability which is inherently lacking in markets for many secondary materials.

Furthermore, if, at some future date, it becomes economically more attractive to recover waste paper and plastics as secondary materials rather than as a fuel, then it would be comparatively easy to modify an RDF process to achieve this. All RDF processes separate out and recover ferrous metals, this being essential to the production of the fuel and can also provide useful extra income at little extra cost.

Pyrolysis Processes

Pyrolysis is a process whereby organic compounds are broken down into simpler substances by heating in anaerobic conditions.

The products generally produced through pyrolysis of municipal solid waste, while varying in proportions, comprise fuel gases; an oily mixture; tars; organic compounds and solid chars.

The range of temperatures applied also greatly affects product distribution. Broadly speaking, lower temperature pyrolysis processes tend to produce predominantly solid and liquid products while the higher temperature processes result in an inflammable off-gas and a small quantity of solid residue.

A summary of pyrolysis processes under development is shown in Table 3. Much of the development work on waste pyrolysis has been carried out in the United States, though some research work has taken place in the U.K., Sweden and the Federal Republic of Germany. Pyrolysis, as a method of treating and recovering products from solid waste, is still at an early stage of development, and despite the fact that several large-scale plants have been built and operated, the technology itself is far from commercially proven.

Published and estimated capital costs for pyrolysis processes are usually at least as high as those for incineration with heat recovery and can, in certain circumstances, be even higher. Comparison of the operating costs of different pyrolysis systems has indicated that pyrolysis, like incineration, is susceptible to substantial

Table 3. Examples of Waste Pyrolysis Systems Under Development

	Process	Location	Capacity 24h throughput	Status	Maximum Reactor Temperature °C	Waste Pulverisation Necessary	Production of Usable Surplus Energy Possible
Mixed Process (Pyrolysis with partial incineration)	Landgaard (Monsanto)	Baltimore (USA)	900t	Demonstration plant in operation	1000	yes	-
	Andco-Torrax	Orchard Park, Buffalo (USA) Luxembourg Frankfurt-am-Main (FRG)	75t	Test operation (in Luxembourg)	1700	no	-
	Purox (Union Carbide)	South Charleston (USA)	200t	Test operation	1700	yes	-
	Pyrogas (Motala)	Gislaved (Sweden)	50t	Test operation	1500	no	-
	Krupp Hoval	Mobile demonstration plant (FRG)	Only batch operation possible	Demonstration	-	no	-

Table 3. (Continued)

	Process	Location	Capacity 24h throughput	Status	Maximum Reactor Temperature °C	Waste Pulverisation Necessary	Production of Usable Surplus Energy Possible
Pure Pyrolysis Processes (Exclusion of Air)	Destrugas	Kalundborg (Denmark) Licensed plant in Japan	5t	Test operation complete	1000	yes	yes
	Fluidised-bed process (Prof. Sinn)*	Hamburg (FRG)	-	Laboratory-scale operation	600-900	yes	(Oil, char, ZnO)
	Herko/Kiener*	Goldshöfe/ Aalen (FRG)	6t	Test operation	600	yes	(Oil, char)
	Kiener System	Goldshöfe/ Aslen (FRG)	6t	Test operation	600	yes	yes
	Pyrol	Stanford Research Institute (USA)	-	New development	-	-	-
	Gelsenberg-Mannesmann Umweltschutz GmbH*	Bochum (FRG)	5t	Test operation	700	yes	(Oil, char)
	Krauss-Maffei	Munich (FRG)	-	New development	-	-	-

* Waste materials used: Used tyres, mixed plastics, cable wastes, wood. Less suitable for household wastes.

economies of scale, and must be operated consistently at throughputs close to design capacity if unit costs using pyrolysis are to be brought down substantially below those of a comparable incineration plant.

Those pyrolysis systems producing a fuel gas will normally require a user (or, in the case of a large plant, several users) in close proximity to the plant. In theory, it is possible to liquify the gas for storage and transportation, but it is doubtful whether liquefaction can be justified in terms of the additional capital and operating costs that this would entail.

The high temperature pyrolysis processes usually produce a friable, inert residue, which may in principle be used for a variety of construction purposes, e.g. road metalling, as a bulk aggregate, etc. It seems unlikely that this residue could be sold, unless a major consumer could be found very close to the plant. The char and oil/chemical products associated with lower temperature pyrolysis systems are usually intended as substitutes for conventional fossil fuels, though experience with using these products is very limited.

Environmentally, the flue gas volumes from pyrolysis are generally considerably less than those produced by incineration and, consequently, gas cleaning requirements (and related costs) are reduced.

The overall volume reduction achieved with pyrolysis is high (comparable to incineration) and the residue is ideal for landfilling, where no user can be found nearby. As mentioned earlier, pyrolysis systems involve a very high capital outlay, and it appears that this method of recovering wastes might only be economically attractive in certain circumstances, i.e. in dense urban areas where a large capacity plant can be supported and where potential users for the gas and oil products can be found in close proximity to the plant.

Coupled with this, there have been reports from the United States of technical operating difficulties with some pyrolysis systems, e.g. the Monsanto Landgard system at Baltimore. It appears that small scale pyrolysis plants might only be eventually attractive as a method of treating and recovering certain high calorific value, difficult, wastes, e.g. used tyres, mixed and contaminated industrial plastic wastes.

Composting Processes in Combination With Some Form of Preliminary Sorting

As pointed out earlier, certain fractions of municipal solid waste are more suitable for composting than others. The application of composting in combination with some form of preliminary sorting (e.g. materials recovery or RDF production) has distinct potential advantages over the more conventional composting systems. The main advantages are:

- Composting the more suitable, pre-sorted waste fractions allows a greater degree of control over the homogeneity and mixing of the compost raw material, leading to a better quality compost product and a greater likelihood of being able to introduce standard specifications;

- the total yield of a combined sorting and composting plant is substantially improved (to 70-80 per cent), and therefore smaller quantities of residue remain to be landfilled;

- total operating costs per tonne of waste processed might be noticeably reduced;

- such a plant would allow greater flexibility for composting certain other types of wastes (e.g. sewage sludge, bark, some types of agricultural waste).

This form of composting therefore removes some of the difficulties associated with conventional composting of refuse, and could be expected to benefit both the value of the compost product and the development of the required markets.

Other Chemical or Biological Processes

Under this heading, one could include such processes as hydrolysis, methanation, ethanol production, single cell protein production, etc. Some of these processes have traditionally been used for converting and recovering certain types of industrial waste, e.g. in the sugar and pulp and paper industries.

However, the application of these processes for treating and recovering domestic refuse poses conditions and operating requirements very different from those prevailing in industry. Apparently there are no large-scale processes of this type being built for processing domestic refuse, though methanation is finding increasing use as a method of treating sewage sludge.

The very limited information available suggests that the capital costs are likely to be quite high because of the eleborate process controls required. Even though research is being conducted with the eventual aim of introducing these processes into large-scale operation, it is likely to be many years before they achieve a practical role in resource recovery from highly contaminated, mixed solid wastes.

ECONOMIC CRITERIA OF IMPORTANCE FOR SOLID WASTE TREATMENT/RECOVERY

The potential benefits (and associated costs) of recovering products from waste can be broadly divided as follows:

- Those accruing to the persons or organisations with the responsibility for handling and disposing of wastes;

- those accruing to the users of recovered materials/ products;

- those accruing to the community as a whole.

Each will have a different view of the attractiveness of reclaiming wastes, which can in certain circumstances conflict.

The attractiveness of recovery as a method of handling waste depends on how the costs and benefits of the available recovery methods compare with the costs of the conventional methods of waste collection and disposal that would otherwise be employed.

From the point of view of the responsible authority recovery should be of interest if the cost of collecting the material or product plus any cost of sorting or separation of the material or by-product generation less any saving in overall waste collection and disposal costs is less than the revenue obtained from the sale of recovered materials, energy or other by-products.

It is important to be clear that the relevant waste collection and disposal costs for this calculation are the marginal savings to be obtained as a result of reclamation, not the average level of collection and disposal costs for all wastes. In practice this point is frequently disregarded since marginal savings can be difficult to calculate. Sometimes average costs are used or, alternatively, potential savings are themselves ignored.

From the point of view of the user of resources, products recovered from waste represent an alternative to products derived from virgin or primary sources. However, the products can rarely be used directly in the form in which they are initially recovered from the waste stream and, even if there has been some prior sorting and treatment, additional processing to upgrade the recovered product is often required, or it may be necessary to adjust the method of manufacturing the final product so as to accommodate the use of recovered materials/energy/or by-products.

In addition to the cost of obtaining and processing materials/energy, there are the costs of transporting the materials or product between the various stages of operation; the importance of these costs varies greatly in different circumstances.

If the common elements in costs are eliminated, the choice between using virgin or reclaimed material by-products can be simplified down to the following calculation.

It will be worthwhile using reclaimed material if the cost of buying the reclaimed material/energy (ex-collection vehicle, -initial sorting point or -recovery plant) is less than the cost of purchasing or producing virgin material/energy less any extra cost involved in processing and using reclaimed material/energy less any additional transport costs involved in obtaining the reclaimed rather than the virgin material/energy.

As with the similar calculation for the worthwhileness of recovery as a waste handling option, the key cost elements are marginal ones, those resulting from changes from the existing situation.

These costs will differ in the short or long term, and between the producer already operating a plant using virgin material/energy and the organisation considering setting up a new plant.

In the case of an existing plant, the extra costs involved in changing to the use of reclaimed materials/energy may be high, either in terms of expenditure on new processing equipment or extra transport costs, or both. But, if a new plant is being considered, a production system specifically designed to handle reclaimed material/energy can be used, which may not be much more costly than that for virgin feedstock; while transport costs can be minimised by selecting the location of the plant best suited to the resource being used.

The scope for using recovered rather than virgin material/energy, and the level of extra costs for the user to be set against any saving in price, depends in practice on a large number of factors.

These fall broadly under the following headings:

- The technical ability to turn reclaimed material or by-products into an acceptable substitute feedstock;

- the market's attitude to final products made with recovered feedstock;

- the supply conditions for reclaimed as compared with virgin feedstock;

- the location of production facilities in relation to sources of materials/feedstock.

It should be mentioned that the producer and user of recovered products need not be separate organisations. Indeed, some integrated concerns in the US and Europe collect and process waste, recover various products and materials, and use these in their own manufacturing plants. Conversely, several independent organisations may be involved at different stages in the sequence of recovery, processing and conversion.

The third view of the attractiveness of resource recovery from waste is that of society as a whole which, for a number of reasons, may not coincide with the views of the waste handling authority or the user of raw materials and resources. For example, other issues which the Government may need to consider in its assessment of the costs and benefits of resource recovery from wastes include:

- The value to the country of the waste materials currently not being recovered;

- the value of this material in terms of saving of imports and scarce raw materials (including energy);

- the impact of recovery on pollution of the environment and destruction of amenity;

- the social effects consequent upon additional recovery (e.g. impact on employment).

Such issues tend not to be of main concern to local authorities or individual industrial organisations.

CONCLUSION

There are few general conclusions which can be made about the viability of different methods of recovery from wastes for so much depends on local circumstances.

However, the decision on whether or not to mount a concerted effort to recover from wastes as part of an overall waste management strategy depends mainly, but not exclusively, on economic considerations. Nevertheless, the following points, taken from the 1973 report to Congress by the US Environmental Protection Agency, succinctly summarise the position on the potential for resource recovery from most of the mixed solid wastes currently destined only for disposal:

"(a) The use of recycled materials appears to result in a reduction in atmospheric emissions, waste generated, and energy consumption when compared with the use of virgin materials.

"(b) The recovery of materials from waste depends largely on economics. The cost of manufacturing products from secondary materials is generally as high or higher than manufacturing from virgin materials. Consequently only high quality and readily accessible waste materials can find a market.

"(c) There has been sufficient technological development to allow extraction of materials from mixed municipal wastes. But the cost is high and makes recovery attractive only in areas where high disposal costs prevail and favourable local markets exist for recovered materials.

"(d) Recovery of materials (as opposed to energy) from mixed municipal wastes, while conceptually the best alternative to disposal, cannot be instituted on a large scale without:

- substantial reduction in processing costs and/or upgrading in quality

- major re-ordering in relative virgin and secondary material prices, to make secondary materials more attractive.

The former is simply unattainable given reasonable projections of present technology."

A REVIEW OF WASTE MANAGEMENT AND RESOURCE RECOVERY REGULATIONS

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INTRODUCTION

It is not the purpose of this paper to examine the legislation and regulations governing the collection and disposal of waste; that is a subject better dealt with by a lawyer and there are a number of detailed comparative reviews available (McLoughlin, 1976).

The aim of this paper is rather to review the approach and policy being adopted by governments in particular in Europe and the US to control waste and encourage resource recovery (Bidwell, "Recycling Policy: an International Perspective").

This subject is discussed under 3 headings: the rationale for these programmes; the types of action that can be taken and the selection of the most appropriate measures.

RATIONALE FOR ACTION

There are 3 principal reasons why, since 1970, European and US governments have turned their attention to waste reduction and resource covery. These are as follows:

Reduction in the Use of Resources

The disposal of waste obviously involves some loss of material. Estimates for the EEC countries suggest that each year around 100 million tonnes of potentially recoverable materials are thrown away: included in the waste is over 20 million tonnes of paper, 15-20 million tonnes of ferrous metals, about 10 million tonnes of glass and between 1-5 million each of non-ferrous metals, rubber, plastics, textiles and waste oils. In addition to the potentially recoverable materials large quantities of residues from agriculture, food processing, mining and power generation many of which are potentially usable in one form or another ("Economics of Recycling", 1976).

Many of the materials lost are imported so there are good economic and strategic reasons for any government to decide to recover materials from wastes. Furthermore, some materials are relatively scarce and the governments feel it a social duty to ensure that these should not be discarded unnecessarily. Certainly reduction in the use of resources has been a major impetus for government action in Europe:

- Loss of potential raw materials is specifically identified in the paper setting out the United Kingdom Government's views on recycling (War on Waste, a Policy for Reclamation, Cmn 5727, HMSO, London, 1974).

- It is recognised by the French Government both in their recent report (Ministry of Quality of Life, 1974) and as an objective for setting up their Raw Materials Commission (France: Decree No. 75-200, 1975), one of whose aims is to reduce raw material use through recycling.

- In Sweden, an important factor in the programme to encourage waste paper recycling has been the need to avoid a shortfall in the raw material for paper products, since this is one of the country's most important exports (Sweden: SFS 1975).

- The Netherlands, in an unpublished note on recycling policy, observes that one reason for encouraging recycling is the reduction in the consumption of energy associated with the use of recycled material as compared with primary ores.

This last one, the use of energy, has played a role in the thinking of some governments. However seen from a totally nationalistic rather than global viewpoint, it must be recognised that the energy for basic smelting and refining is often used before the material is imported and any saving will therefore arise from importing less of the material rather than from saving very much energy. There are of course exceptions: glass is often manufactured from local resources and recycling glass using cullet can give savings of 10-20 per cent compared with use of raw materials.

<u>Reduction in the Quantity of Waste Requiring Disposal</u>

In Europe and elsewhere local disposal sites are becoming increasingly hard to find in those areas where they are most needed. The alternatives such as incineration and long haul to landfill are expensive. Reduction in the quantity of waste requiring disposal can therefore result in a very real saving.

This does however depend on the individual circumstances. For example if the waste from a particular area is incinerated and that incinerator is working at full capacity, measures to prevent any increase in the quantity of waste may avoid the need for a new facility. But if the incinerator is not fully utilised then the reduction will show little benefit.

Similarly with collection: if every householder reduces the amount of waste by 10 per cent it will not necessarily mean that 10 per cent fewer men and vehicles are required. But in general and in the longer term, waste reduction measures may be expected to be beneficial. Governments have been looking at ways to reduce the amount of waste requiring disposal and prior to the post 1973 increase in resource costs, it formed probably the principal objective. So the German Federal Government in their 1975 Waste disposal Programme note (Berlin, 1975) state that, while in 1971 they were concerned primarily with "problems of systematic waste disposal," now the cost in manpower and resources of providing disposal services, the need to protect the environment, and the dependence of the country on imported raw material supplies are identified as 3 main reasons for action: the programme proposes that such action should not be confined to systematic waste disposal but rather should "strive for a reduction in the amount of, and increased utilisation of waste".

In the United States, waste disposal and the litter problems are given greater emphasis than resource savings. In 1970, the President, in a message to Congress proposing, inter alia, an extension of the Solid Waste Disposal Act, suggested the need to redirect research so as "to place greater emphasis on techniques for recycling materials and on development and use of packaging in other materials which will degrade after use". The message also noted that existing packaging methods, with an emphasis on "non-returnable bottles and cartons" had created an increasing volume of waste and refuse; and the traditional method of dealing with the problem was to continue spending money on collection and disposal of wastes which "amounts to a public subsidy of waste pollution" (Congressional Quarterly Almanac, 1970).

Prevention of Environmental Damage and Litter Reduction

So far as municipal refuse is concerned, prevention of environmental damage usually requires good management rather than more fundamental action. But the aims of preventing environmental damage and reducing litter usually receive a mention in recycling-waste reduction programmes; for example, in the United Kingdom Government's "War on Waste" (War on Waste, a Policy for Reclamation, Cmnd 5727, HMSO, London, 1974) and the French "La Lutte Contre le Gaspillage" (Ministry of Quality of Life, 1974). These aims tend to be of importance in the case of specific recycling programmes such as the recycling of waste oils (to minimise pollution) and controls over packaging materials. There is some doubt about whether programmes designed to reduce waste are of much assistance in reducing litter; but in the United States, litter reduction appears to have been the primary objective of the Oregon Legislation to control beverage containers (USEPA, 1973). It is of interest to note that similar regulations in Sweden were brought in primarily to help finance the freeze on the prices of certain food products (Olson, 1975).

The EEC summarised the rationale for action very succinctly in their recent Environmental Action Programme (EEC Council Resolution; Official Journal No C139).

"The protection of the environment against pollution, sound economic management of resources, the effort to reduce the Community's dependence on imported raw materials, the rational long-term management of natural resources which are either non-renewable or can be renewed only at a certain rate - all these considerations together argue in favour of an immediate and hard-hitting campaign against waste" (EEC Council Resolution; Official Journal No C139).

TYPE OF ACTION

Before deciding the type of action that is required, it is necessary to resolve 2 questions:

- What are the objectives of the action?
- What are the specific problems that the action is designed to overcome?

The Objectives

The objectives are likely to determine the priorities for actions. Programmes primarily designed to reduce the amount of refuse requiring disposal are likely to concentrate, certainly in Europe, on packaging materials since these account for up to 50 per cent of the total weight. This has been an important objective of the solid waste programme in Germany and France. On the other hand programmes which are principally designed to reduce dependence on imports may select other priorities: the French Raw Materials Commission has looked carefully at plastics, copper, textiles, phosphates, and the energy and paper aspects of packaging.

In the United Kingdom, however, emphasis has been given to encouraging reclamation which can be shown to be economic (Kruse, 1976); so attention has been paid to further recovery of ferrous and non-ferrous metals. In Sweden where the economy is particularly dependent on ferrous metals and paper exports, there has been some emphasis on minimising the indigenous use of these materials and recovering more waste paper and metal from abandoned vehicles.

The Problems

Any action that is developed will need to take account the reasons why materials are currently discarded as wastes. The fundamental problem may be that it is just not economic. But there may also be other problems that act as a disincentive to further recycling and which may partially determine the overall economic feasibility:

- There may be no demand for the waste materials.

- They may be difficult to separate out and recover in a form uncontaminated by other materials.

- Quantities of individual arisings may be low so transport may prove disproportionately expensive.

- Producers and users may have insufficient technical and market information on the availability and use of the materials.

- There may be difficulties in guaranteeing a continuous supply.

- Consumers may find materials manufactured from recovered materials unacceptable.

The types of action that can be employed to overcome these difficulties are reviewed below and summarized in Table 1.

Lack of Demand

It will be appreciated that there is no point in encouraging people to reduce wastes and recover materials if there is no demand for the recovered materials. This is a fundamental error that many governments make. The most likely result will either be a large unwanted pile of the recovered material (which is bad for public relations) or, where there is an existing market, the secondary material price will be depressed and even the traditional recoverers will drop away.

Demand can be encouraged in a number of ways.

Government Purchasing (Procurement) Policy

That is, the requirement that certain products or materials purchased by public authorities should incorporate in some proportion a secondary material. A number of European governments have plans to or in fact do specify proportions of recycled fibre to be contained in supplies of paper procured for the public sector.

The status of procurement programmes in the United States is reviewed in the Second Report to Congress. The General Services Administration requires that paper procured should include certain proportions of recycled fibre from post-consumer waste as well as from industrial sources: these proportions are established taking into account the performance required, the supply of secondary material and product price. The Department of the Army has a policy of tyre retreading for automobiles and trucks (USEPA, 1974).

Provision of Information

The demand for recycled materials may be limited because potential users may not have adequate information on the availability and use of

Table 1. Summary of Actions by European Governments to Encourage Resource Recovery and Reduce Waste

	LEGISLATION	REGULATIONS, FISCAL MEASURES, ETC.	OTHER GOVERNMENT ACTION
DENMARK	1971, Law on containers for beer and soft drinks.	Voluntary action by industry to restrict non-returnable containers for beer, wine and spirits.	Plans for submission of Resource Recovery Bill in 1978 to enable control of products, particularly paper and board and beverage containers.
		1977, Statutory order prohibiting the use of non-returnable containers for soft drinks.	Government introducing secondary materials standards into public procurement specifications.
	1972, Law on the disposal of oil and chemical wastes.	1972, All waste oil (above 501) must be reported and disposal authorised.	
		1977, All chemical wastes must be reported and disposal authorised.	Recovery of wine and spirit bottles and use of recycled paper by public authorities are under examination.
	1973, Environment Protection Law.		
FRANCE	1975, Law on waste disposal and recovery.	Regulation planned to limit use of certain glues, inks, etc. in some paper products.	Programme of public education including National Agency information service ("svp") on waste disposal and resource recovery.
		Administrative directive on use of recycled paper in public organisations.	Examination of separate collection techniques, waste paper stockpiling, the role of product standards in resource recovery and methods of regulating packaging.
		Tax regulations favour waste oil over primary supplies.	
			Specifications for secondary materials.

Table 1. (Continued)

	LEGISLATION	REGULATIONS, FISCAL MEASURES, ETC.	OTHER GOVERNMENT ACTION
GERMANY	1972, Waste Disposal Law.	Voluntary agreement by industry to restrict packaging. Glass and metal industries have agreed to use more secondary raw materials. Government-industry working group will monitor progress.	Examination of: public procurement specifications, the value of subsidies for local authority waste paper collection, methods of controlling non-returnable containers and the effect of increased disposal charges on recovery. Publicity on waste reduction through product control.
	1969, Waste Oil Law.	Subsidies awarded for collection and use of waste oil, funded by tax on delivered primary supplies.	Development of waste management and resource recovery databank and information service (UBA).
NETHERLANDS	1977, Waste Materials Act.	No regulations introduced yet.	Ministry of Public Health and the Environment has increased use of secondary paper.
	1976, Chemical Waste and Used Oil.	No disposal or recovery regulations introduced yet.	Government gave initial capital support for a waste paper stockpiling scheme. Product controls under investigation.
UNITED KINGDOM	1974, Control of Pollution Act.	Waste Disposal Authorities now required to develop waste disposal and resource recovery plan.	National Anti Waste Programme's "Save and Recycle" campaign for public education and to encourage voluntary activity. WMAC Advisory Papers on the disposal and/or recovery of a wide range of different wastes.

Table 1. (Continued)

	LEGISLATION	REGULATIONS, FISCAL MEASURES, ETC.	OTHER GOVERNMENT ACTION
UNITED KINGDOM (contd...)			A new consortium of textile reclaimers (established by government encouragement) has agreed to guarantee to purchase supplies from organised voluntary collections.
COMMISSION OF THE EUROPEAN COMMUNITIES	1975, Directive on Waste 1975, Directive on the Disposal of Waste Oils 1976, Directive on the Disposal of PCBs. 1976, Proposal for directive on toxic and dangerous wastes.	Codes of practice to be drawn up on recycling and disposal of specific wastes.	Committee on Waste Management, priorities for study are: - toxic wastes, - waste paper, - the use of waste as energy, - the use of agricultural wastes, - waste material exchanges. Under the waste paper programme the Committee is to propose action on: - increased use of recycled paper by the public sector, - contamination of paper products - separate collection of certain grades of waste paper and develop a publicity programme on the use of waste paper. CREST Sub-committee, secondary raw materials group is continuing its work to coordinate national research effort and establish joint research programmes.

Table 1. (Continued)

	LEGISLATION	REGULATIONS, FISCAL MEASURES, ETC.	OTHER GOVERNMENT ACTION
SWEDEN	1975, Waste Disposal Law (No. 495)	1976 regulation requires that by 1980 all households, shops and offices must separate waste paper for collection (except in areas where this is impractical). 1973 Beverage container tax and mandatory deposit regulations. 1975 Car scrapping premium regulations.	The impact of an increase in container tax recently examined.
NORWAY	1976, Product Control Act.	First products to be controlled under the Product Control Act to be toxic and dangerous substances.	Wine and spirits' state monopoly repurchases empty bottles.
	1974, Provisional Law on deposits for packaging for beer, mineral waters and soft drinks. 1978, Bill to regulate waste disposal and resource recovery in preparation.	1974, Beverage container tax and mandatory deposit scheme.	Environment Ministry provides loans to finance waste paper stockpiling.

suitable secondary materials. In this case, the government may assist by setting up of information centres to hold relevant data. In Europe, there are a number of publicly and privately sponsored waste material exchanges: for example, in the United Kingdom, Scandinavia, the Netherlands, Germany, Austria, Belgium and Italy.

Research and Development into Technical Problems

As noted above, there may be technical (practical) obstacles to the demand for secondary materials. For example, it may prove difficult (and costly) to clean and upgrade a particular material to a quality acceptable to potential users. Where it is clear that the main obstacle to demand for a specific recycled material is a technical problem, R and D may be subsidised by the government. Problems of this type that have received attention in Europe include investigation into methods of de-inking and upgrading waste paper, de-tinning and research into new uses for materials that are difficult to recycle or re-use. Examples of this research include the search for new uses of cullet and the development of building materials from pulverised fuel ash and from refuse residues.

Much of the R and D work of this type has been undertaken by the private sector; government-sponsored R and D has concentrated more on the supply problems of initial reclamation and materials separation

Regulations to Overcome User Problems

Consumers may prefer their products made from primary materials; for example, preferences for bleached paper and clear uncoloured glass.

Measures may be taken to prevent unnecessary discrimination against secondary materials or products incorporating the secondary material. For example, the French waste law prohibits the discrimination against the presence of recovered materials and products which satisfy regulations and standards; it also prohibits any publicity based on the absence of recovered materials (France: Loi No 75/633, 1975, Art. 18,19). Such regulations may be supported by further regulations laying down quality specifications for secondary materials and products - in France, the Raw Materials Commission, the French Standards Organisation (AFNOR) and the International Standards Organisation have examined whether primary materials in specifications can be replaced by secondary materials.

Other Measures

Finally, demand may be stimulated by action encouraging the use of secondary materials in products or stimulating the re-use of products through regulations or fiscal incentives. The Raw Materials Commission in France has stated that it is actively considering ways of increasing the use of recycled materials in products and the Government has powers to fix a minimum proportion of recoverable materials, or components to be used in the manufacture of products or product categories (France: Loi No 75/633, 1975). Primary materials may also be taxed at the expense of secondary materials (or secondary materials subsidised); in Germany, France and Italy reprocessing oils is made financially attractive in this way.

Problems of Supplies

For some materials there may be a strong demand (e.g. the metals) and government action may be required to encourage further recovery; in other cases, supply may fluctuate and the government may principally be concerned with trying to stabilise the supply and demand.

Fiscal Incentives

Fiscal incentives may be used to promote recovery and make the material available for recycling. Under Swedish legislation (Sweden: SFS 1975) an owner, before he can de-register his car (and cease paying a car tax), must be issued a certificate from an authorised person (e.g. a vehicle-breaking company) confirming that the vehicle has been received for scrapping. Every car manufactured or imported into Sweden from 1976 bears an additional charge of 250 Swedish crowns (about US$55); the car owner will receive a premium of 300 Swedish crowns when the car is de-registered.

In Germany, the Waste Oil Law (Germany:Waste Oil Law, 1969) provides for the payment of a subsidy if the waste oil is collected and used in an approved manner. In France, the law (France: Loi No 75/633, 1975) enables the authorities to require that waste disposal methods should, where possible, allow for material and energy recovery.

Measures may also be taken to ensure the return of products that can be re-used and that might otherwise be discarded as waste: in practice, this means containers made of glass, metal and to a lesser extent, plastic. In Sweden, there is a tax at the point of manufacture on all beverage containers whose contents are more than 0.2 litres and less than 3 litres. In Norway, there is a tax on one-way containers and the deposit on recoverable containers is fixed by law (Oslo: Law No 35, 1974).

In the United States, a number of states are considering, or have taken, action to encourage the re-use of containers. The first was Oregon, whose "Bottle Bill" was passed by the state legislature in July, 1971 and became effective on October 1, 1972. The purpose of the legislation was to control litter (USWPA, 1973) and it required that a 2 cent deposit should be levied on all standard bottles that were refillable by more than one bottles; and a 5 cent deposit for all other containers, such as non-standard bottles (for example, bottles with trademarks).

The EPA has proposed guidelines for beverage containers; in particular, the guidelines require that carbonated beverages sold in federal establishments should be sold in returnable beverage containers on which there would be a deposit of at least 5 cents (Federal Register, 1975). The Commission of the European Communities is currently examining questions of container re-use.

Research and Development to Overcome Technical Problems

The US and most European governments have made finance available for research and development into separation and up-grading technologies. In particular, Germany, the United Kingdom and the Netherlands have all provided finance for the development of materials' separation systems. In the US the 1970 Resource Recovery Act allowed for grants by public agencies for resource recovery demonstration plants or construction of innovative waste disposal facilities. The federal share of demonstration grant was set at 75 per cent; the federal share of construction grant was set 50 per cent if the project served any one municipality and 75 per cent for joint projects. Whether or not such a high level of expenditure on such projects is justified in terms of its eventual return or benefit to the community is a matter of opinion; of the large number of systems that receive assistance, only a few would appear to be commercially viable. There may be a case for more selective assistance by government.

Regulations to Overcome Technical Problems

The availability of secondary materials may also be limited by technical difficulties in recovering and separating materials (particularly from mixed wastes and from products made from different materials). Where technical problems arise from product characteristics, these can be controlled by government regulation. A number of European governments have the power to require that specific products are changed to facilitate their recovery or disposal.

In France, the Council of State is able to regulate, by decree, methods or using certain materials, components, or energy so as to facilitate subsequent recovery (France: Loi No 75/633, 1975). In Germany, while there is no legislation, the Government has noted (Berlin, 1975) that some products contain different mixtures of materials whose recovery is difficult and expensive, and it is therefore necessary that waste management measures should start at the product design state; to this end a degree of standardisation may be required. In the Netherlands, the Government can regulate or prohibit the manufacture or sale of certain goods which, because of their nature, composition, weight, or volume are difficult to recover (Netherlands, 1977).

Provision of Information

Central government may play a valuable role in providing industry and local authorities with information on recovery and waste management.

The French Government produces and circulates booklets in an easily readable question-and-answer form; the first was on separate collection schemes (Ministry of Quality of Life, 1976); the UK Government has distributed advisory papers aimed principally at waste disposal authorities (HMSO Waste Management Papers); and the German Environment Agency is at present establishing a data bank to hold information on European recycling and materials re-use.

A review of action would not be complete without mentioning measures that have been taken to try and stabilise prices in the secondary materials' market and so overcome fluctuations in supply and demand that have been particularly damaging in Europe. Two methods have been tried.

The first type of measure involves the use of public money to finance stocks of secondary materials during times of low demand. Excess-stock schemes for paper to reduce the effect of peak and trough in demand have been examined or implemented in a number of countries including Norway, France, Netherlands and Japan. As with any intervention of this type into the market system, the problem lies in determining at what price waste paper should be bought in and in deciding what action to take if demand remains depressed and the stocks of secondary materials continue to grow.

On the other hand, long-term agreements between waste producers or waste handlers (such as public authorities) and industry may prove a more satisfactory solution. Such agreements can in fact be made at the national level. In Sweden, industrialists within the paper industry were prepared to make investment in increased waste paper processing plants, but they laid it down as condition of such expansion that the supply of waste paper should be guaranteed. The Government responded (according to the Minister for Agriculture and Environment (BIR, 1975) with the regulation (Sweden: SFS 1975) under which householders can be required to separate out newspapers and magazines from their refuse and keep these separately for removal by the local authorities.

SELECTION OF MEASURES

In developing policy to encourage waste reduction and resource recovery there are a number of points that should be remembered. One of the most important is that there are probably very good financial reasons why materials are currently discarded as wastes. All things being equal, action to stimulate recovery may very well increase costs and therefore prices; so a government should satisfy itself that the benefits in terms of the objectives justify any cost increases. There are of course exceptions: in particular, information can be provided cheaply.

Secondly, it is essential for supply and demand measures to be integrated. It has already been noted that unless demand for the recovered materials can be increased, action to improve supply will not result in an overall increase in recycling activities; the only exceptions to this rule are the metals which can be readily substituted for their high-value virgin materials. Similarly, measures to increase demand (e.g. government purchasing of products incorporating secondary materials) should not be implemented unless an adequate supply of the secondary materials can be guaranteed.

Thirdly, it is important to establish that the measures will have the desired result with the minimum of unwanted side effects. This problem of potential distortion and dislocation warrants careful investigation and the potential dangers may even act as a deterrent to fundamental action. It was, for example, noted in the First Report to Congress on Resources Recovery and Source Reduction (USEPA, 1973) that "additional Federal incentives for recycling are not considered desirable at this time. Studies to date indicate that the effectiveness of specific incentive mechanisms that can be formulated is extremely difficult to predict. New tax incentives may well distort the economics of resource utilisation much as preferential treatment of virgin materials distorts them today".

In the case of the Swedish returnable container scheme, Olson, Head of the Swedish Environmental Protection Board, has commented (Olson, 1975) that the main effects of the tax have been to increase the number of containers above or below the limit set by the legislation and to bring about some shift from the use of non-returnable containers. There has perhaps been some decrease in litter, but there is doubt as to whether this results from the tax or the associated publicity; and it has been calculated that there has been a very small reduction in the quantity of solid waste produced per year (of the order of 1.0 kg per person per year) and in the amount of energy consumed (reduction of about 0.01 per cent). Industry has argued that the scheme has conferred few, if any, environmental or economic benefits and has resulted in some unemployment (See Olsen (Olson, 1975) and PLM (PLM, 1975). A more recent report on whether or not to increase the container tax (Stockholm, 1976) has argued that while this may not induce the required consumer behaviour, it will raise money to help in antilitter campaigns.

Finally, it will be appreciated from the above that there are likely to be a number of government departments and organisations with an interest in different aspects of recycling and it is valuable to establish some form of co-ordinating body.

There is no doubt that the rising cost of raw materials and the introduction of more stringent environmental protection standards have encouraged many governments to develop recycling programmes. As has been noted, the main obstacle is frequently that it is not at present sufficiently financially advantageous to reclaim, process and use materials from waste. The first priority is to determine where additional recovery would be most beneficial and whether the additional cost involved would be justified. Once the government is satisfied on this point, the next stage is to identify measures that will achieve the objectives with the minimum side effects.

REFERENCES

Berlin, (1975) "Waste Disposal Programme of the Federal German Government" (Translation of Abfallwirtschaftsprogramm der Bundesregierung).

Bidwell, R., (1977) "Recycling Policy: an International Perspective", Resource Conservation, New York University Press 1977. Also Bidwell, R. and Raymond, K., "Resource Recovery in Europe", NCRR Bulletin, Winter 1978.

BIR, (1975) S. Lundkvist, Swedish Minister of Agriculture and Environment, in an Address Delivered to the General Assembly of the BIR in Stockholm on May 14, 1975.

Congressional Quarterly Almanac, (1970) (p 514). "Solid Waste: Bill Stresses Recovery and Recycling".

EEC Council Resolution on the Continuation and Implementation of a European Community Policy and Action Programme on the Environment, Title 3, Chapter 3, Section 2. Official Journal No C139.

Environmental Resources Limited, (1976) "Economics of Recycling" Report Prepared for the Commission of the European Communities.

Federal Register, (1975) Guidelines for Beverage Containers, first published November 13, 1975 in Register.

France: Decree No. 75-200, 23 April 1975.

France: Loi No 75/633, (July 15, 1975) Elimination des Déchets et Récupération des Matériaux.

Germany: Waste Oil Law, (1969) State Law Gazette 1, p 89.

HMSO Waste Management Papers.

Kruse, E.P., (1976) "Waste Management Policies with Particular Reference to the Reclamation of Materials", paper given at the 103rd Annual Conference of the Institution of Municipal Engineers in June, 1976.

McLoughlin, J., (1966) "The Law and Practice Relating to Pollution Control in the Member States of the European Communities: a Comparative Survey".

Ministry of Quality of Life, Paris, (1974) "La Lutte Contre le Gaspillage". Groupe Interminist riel d'Evaluation de l'Environment. For French recycling policy, see also Les Déchets Solides, Propositions Pour une Politique. Rapport du groupe d'études sur l'Elimiation des Résidues Solides.

Ministry of Quality of Life, (1976) "La Collecte Sélective des Ordures Ménagères: Questions & Responses". Sécrétariat d'Etat de l'Environment.

Netherlands, (1977) Waste Materials Act.

Olson, I., (1975) "Duty on Beverage Containers in Sweden", UNECE Conference on Solid Waste, ENV/SEM3/R2/COM2.

Oslo: Law No 35, (June 14, 1974) "Provisional Law on Deposits for Packaging for Beer, Mineral Wastes and Soft Drinks".

PLM, (June 1975) Taxes on Beverages and Beverage Containers in Sweden.

Stockholm, (1976) SOU 1976: 35. "Dryckes Förpackningar och Miljö". Betankande av Utredningen om Kostnaderna for Miljovarden. (Packaging).

Sweden: SFS 1975: 343: Bilksrotningflag (Car Recovery Regulations).

Sweden: SFS 1975: 495: "Forordning om Statligt Stod Till Avfallsbehandling" (Waste Disposal Regulations).

USEPA, (1973) "First Report to Congress on Resource Recovery and Source Reduction".

USEPA, (1973) (SW-10). "Oregon's Bottle Bill - the First Six Months".

USEPA, (1974) "Second Report to Congress on Resource Recovery and Source Reduction".

War on Waste, a Policy for Reclamation, Cmnd 5727, HMSO, London, September, 1974.

CASE STUDY: EXAMINATION OF DISPOSAL OPTIONS FOR THE ROWANNA SUB-REGION

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INTRODUCTION

The following pages include information relevant to the waste arisings and disposal facilities for a mythical area called Rowanna. This is part of a larger region of a sub-tropical country.

In developing this information, it has been the aim to provide the type of data which a waste management planner would be likely to collect during the first phase of his investigation. It is therefore not altogether complete, consistent or accurate.

Some data on waste handling and costs is included but is just general background information which should give sufficient additional data for the preparation of an outline plan.

THE OBJECTIVE

The objective of the case work is to prepare an outline plan for the region of Rowanna, specifically:

- To assess and, where necessary, analyse and summarise the data into a form suitable for decision making;
- To identify the waste disposal options for the area;
- To outline the implications of each option in terms of cost (capital cost, operating cost, cost per tonne, import requirement etc.) and in terms of impact on the environment (water etc.), long-term security of disposal etc.;
- To prepare recommendations on the preferred option outlining what further investigations will be required.

The objective is not therefore to find a solution but provide a careful analysis of the problem.

ROWANNA

Map 1 indicates the existing land uses in the Rowanna subregion.

The subregion is divided by a river and bounded to the south and east by the sea. The river also forms a dividing line for administrative purposes: there are separate local government authorities to the northeast (NE area) and to the southwest (SW area).

The principal roads and railway links are shown. It can be seen that a single bridge carrying both road and railway joins the two administrative areas.

The NE area has 3 towns A, B and C and is bounded by mountainous country towards the north and low-lying and in parts swampy areas to the south. There is a great deal of agriculture outside the towns and an army training area on the north coast. Town C is a port.

The SW area only has one town of any size (Town D). There is some forestry and agriculture in the area but the principal activity is mineral extraction about 20-30 km northwest of the town.

POPULATION

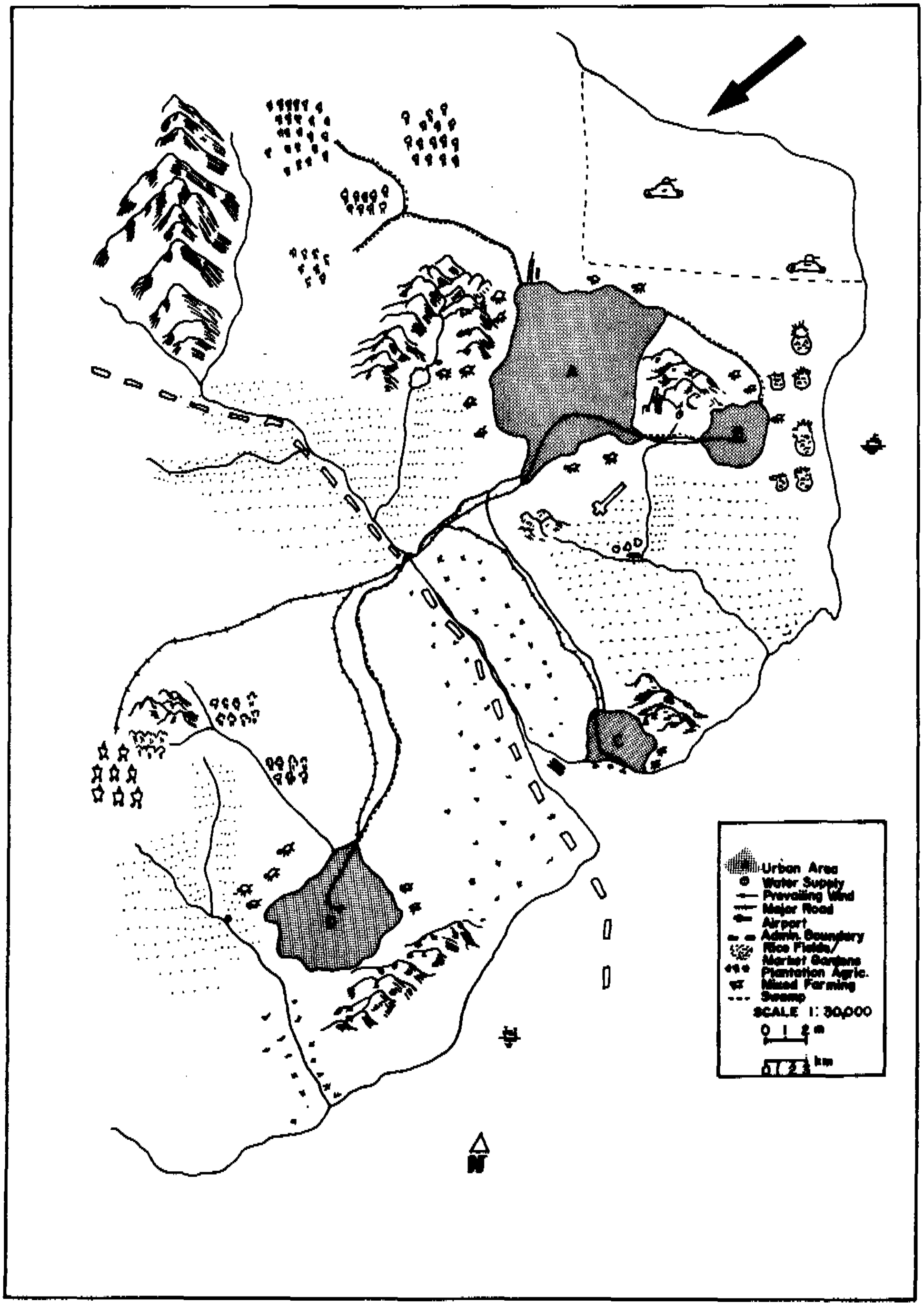
Table 1 indicates the existing and 1985 population of the 4 towns. The areas to which the population figures refer are indicated on Map 2 (solid waste management zones). It can be seen that Town A is very much the largest town with a population of 800,000; it is expected to increase to almost a million by 1985. Town B is a smaller town (around 100,000) which increasingly depends on Town A for jobs etc. The relatively healthy economy (manufacturing industry has achieved an increase in output around about 5 per cent a year for the last 5 years) is likely to result in an expansion of the port facilities (Town C).

In the SW area, Town D, currently with a quarter of a million inhabitants, is expected to grow to almost 360,000 by 1985. This is principally because of its importance in servicing local agriculture but an expansion of local processing industries will also play an important part.

ADMINISTRATIVE AUTHORITIES

The authorities for the NE and SW areas are separately constituted but overall co-ordination is achieved at regional government level. Up until now there has been limited co-operation on public services but future co-operation cannot be ruled out. Town A's prosperity means that the SW area authority (located in Town D) would be unlikely to accept any proposal unless there seems to be some financial benefit.

Population growth in each of the towns is summarised in Table 2.



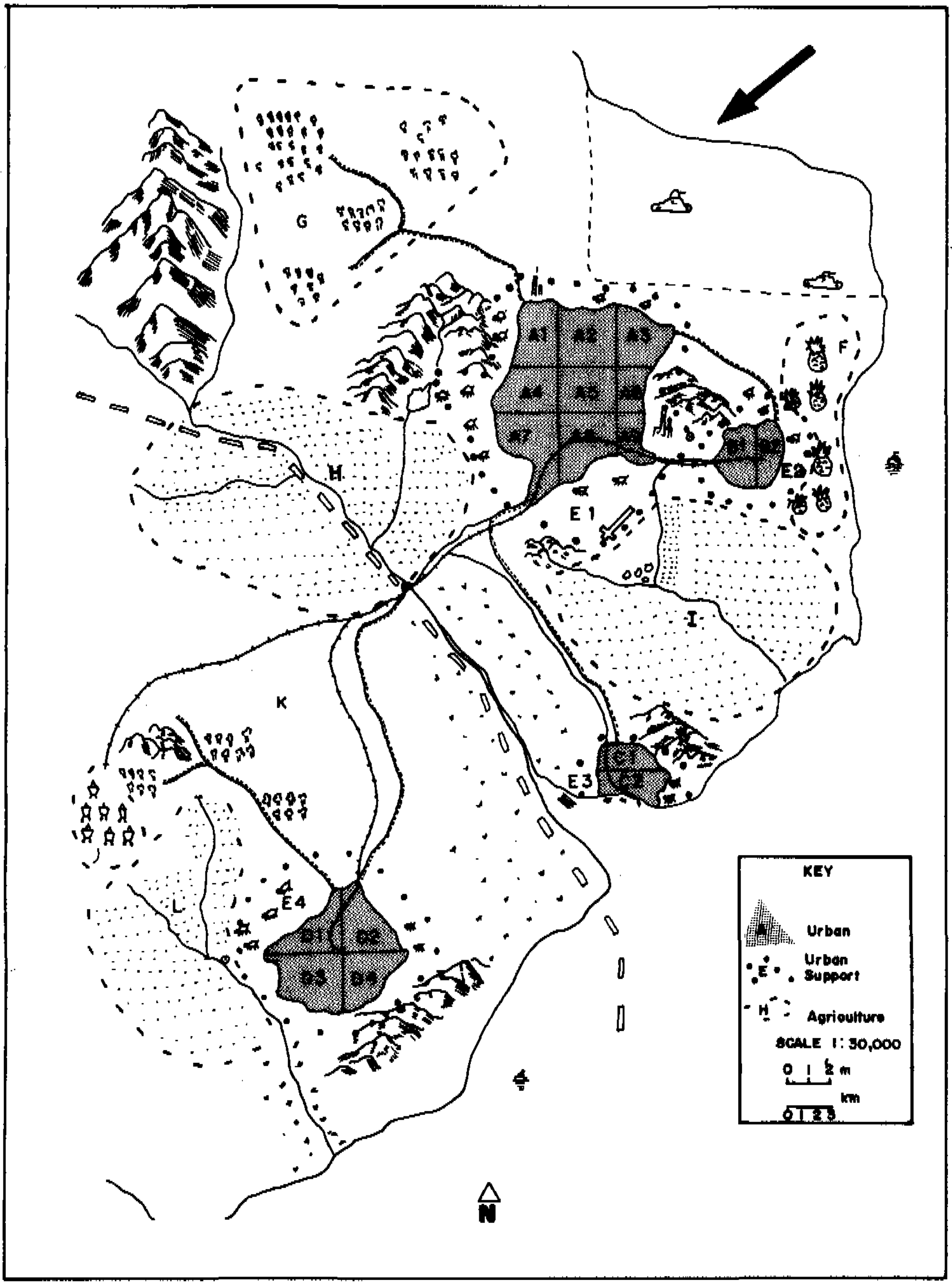
MAP 1. ROWANNA SUB-REGION; LAND-USE 1978

Table 1 - Metropolitan Population Growth 1978-1985 (See Map 2)

Area	Description	1978-1985 Annual Growth 3 Per cent					
		1978		1985			
		No.	% of total pop.	No.	% of total pop.	Pop. incr-ease	Change in % p.a.
TOWN A	A rapidly expanding Regional capital.	800,000	100.00	980,000	100.00	184,000	3.0
Sectors							
A1	Major growth resulting from rural in-migration.	100,000	12.5	180,000	18.3	80,000	+5.8
A2	Quite stable. Housing stock improving.	200,000	25.0	220,000	22.3	20,000	-2.7
A3	Processing industries starting to locate here as a result of labour availability and increasing agricultural productivity.	130,000	16.2	160,000	16.3	30,000	-1
A4	Stable residential. New growth is in-fill development.	70,000	8.7	75,000	7.6	5,000	-1.1
A5	Large scale inner-city redevelopment scheme under way. Prestigious high rise development on under-utilised utility land	60,000	7.5	90,000	9.1	30,000	+1.6
A6	Stable	50,000	6.2	52,000	5.3	2,000	-.9
A7	Migration from city centre. Housing Commission high rise development scheme.	65,000	8.1	73,000	7.4	8,000	-.7
A8	In-fill and consolidation of existing housing stock.	75,000	9.4	81,000	8.2	6,000	-1.2
A9	Housing stock improving through government building programme.	50,000	6.2	53,000	5.4	3,000	-.8
TOWN B	Naturally expanding Processing Centre	100,000	100.00	119,000	100.00	19,000	+2.2
Sectors							
B1	Increased commuting function to Town A. Redevelopment around Town Centre.	60,000	60	74,000	62.2	14,000	+2.2
B2	General housing stock deteriorating. Rural-urban migration.	40,000	40	45,000	37.8	5,000	-2.2

Table 1 - (continued) (see Map 2)

Area	Description	1978-1985 Annual Growth 3 Per cent					
		1978 No.	1978 % of total pop.	1985 No.	1985 % of total pop.	Pop. incre-ease	Change in % p.a.
TOWN C	Fishing activity increasing. Greater movement of export and import trade corresponding to sub-regional growth.	80,000	100.00	106,700	100.00	26,700	+4.2
Sectors							
C1	Consolidation of existing area. In-fill in vacant blocks.	60,000	75	66,000	61.8	6,000	-13.2
C2	Residential growth in new urban development scheme of good quality.	20,000	25	40,700	38.2	20,700	+13.2
TOWN D	Agric. Processing Centre. Rural Service Centre. Expansion of tin mine. Construction of new timber mill.	250,000	100.00	358,870	100.00	108,870	+5.3
D1	Rural-urban migrants settling on urban fringe. Markets increasing in size.	50,000	20	85,000	23.7	35,000	+3.7
D2	Processing industries expanding. Poor quality residential development. Road surfacing and other urban services falling behind.	85,000	34	125,000	34.8	40,000	+0.8
D3	Housing stock being revitalised through government programme.	60,000	24	80,000	18.4	20,000	-5.6
D4	High rise housing occuring. Internal migration focus.	55,000	22	68,870	19.2	13,870	-2.8



MAP 2. ROWANNA SUB-REGION; SOLID WASTE MANAGEMENT ZONES

Table 2 - Rowanna Sub-Region Metropolitan Growth Summary

Town	Descriptions/ Functions	1978	% of Total Metro. Pop.	1985	% of Total Metro. Pop.	1978-1985 Expected Annual increase %	2000	% of Total Metro. Pop.	1985-2000 Expected Annual increase %
A	Regional Capital Commercial Industrial Manufacturing	800,000	65.0	984,000	62.8	3	1,343,900	61.3	2
B	Agricultural Processing Satellite to A	100,000	8.2	116,500	7.4	2.2	145,800	6.6	1.5
C	Port Fishing Trading	80,000	6.5	106,700	6.8	4.2	166,200	7.6	3.0
D	Agric. Processing, Rural Service Centre, Mining Support	250,000	20.3	358,900	22.9	5.3	535,200	24.4	2.7
Sub-region		1,230,000	100.0	1,566,000	100.0		2,190,900	100.0	

WASTE ARISINGS

Table 3 indicates current estimates of waste arisings for each of the areas indicated on Map 2. These waste arisings are analysed into the principal categories: commercial and domestic, industrial and general, agricultural, food and processing and others. In some cases the other wastes are identified.

It can be seen that overall arisings for the area amount to almost 1,700 tonnes per day of waste from all sources.

There are preliminary estimates and have been derived by limited sampling, surveys and through use of available data on population, industry etc.

The quantity and type of waste arisings may be expected to change in the coming years; as noted above the population is expanding and industry is thriving. While the overall estimates of future population are reasonably accurate (see Table 1) there is of course some doubt as to whether growth will occur in the areas shown. Similarly, while manufacturing industry and food processing has been extremely successful in recent years, no one can foresee whether this rate of expansion will continue or not.

WASTE COMPOSITION

Table 3 gives a general idea of the nature of the wastes. However, some analyses have been carried out and the results of these are indicated in Table 6.

DISPOSAL FACILITIES

Existing disposal facilities are described in Table 4 and their location is shown on Map 3; possible options for future sites are listed in Table 5 (positions shown on Map 4).

It will be noted that some of the waste from Town A is composting. The plant is only working to about 50 per cent of its capacity and, on an annual basis, the throughput of the plant is only around 50,000 tonnes. This is because of breakdowns and the way the collection service is organised. But the principal problem has always been to find an outlet for the soil conditioner.

It will also be seen that with the exception of site 4 (which has its own problems) the existing sites have a limited future. The figures for throughput for landfill sites indicate maximum week-day levels. Densities of refuse are indicated in the waste handling summary.

A survey has been carried out to identify future disposal sites. By 1980, it is expected that the composting plant will be relatively old and the problems of breakdown etc may be expected to have increased; a decision therefore will be required on whether or not to replace it. The site survey has looked not only for new landfill possibilities but also possible sites for new transfer or treatment plants (such as No. 8 and No. 2).

Map 4 also indicates those areas where development is expected in the period 1978-1985 and 1985-1999.

Table 3 - Waste Arisings by Quantity, Area and Type 1978 (See Map 2)

Area	Principal Functions/Description	Types of Waste (tonnes per day)				Total
		Commercial and Domestic	Industrial General	Agric. Food Processing	Other	
TOWN A	Administration Commerce Manufacturing Industrial	473	80.0	87.0	64	704
Sectors						
A1	Depressed residential	45		15 (pigs)	6 (cars)	66
A2	Residential	116				116
A3	Depressed residential	75		75 (pigs)	5 (cars)	100
A4	Residential	41				41
A5	*Commercial *Offices Residential	35 + 30 *			20 (earth excavation)	85
A6	Residential	29				29
A7	Manufacturing Markets Residential	37	60 (tin smelting) 10 (metal work)	35		142
A8	Institutional - Residential	43			30 (demolition)	73
A9	Manufacturing Depressed residential	22	10 (kilns)	10 (rice) 7 (pigs)	3 (cars)	52
Sector						
E1	Urban support activity Pigs Chicken Aerodrome etc.	15 (uncollected)	20 (cement)	70		105
TOWN B	Agric. Processing Centre	53	10	50		113
Sectors						
B1	Residential Commercial	35				35
B2	Processing and Manufacturing Depressed residential	18	10 (wood-working)	30 (rice husks) 20 (pineapple waste)		78

Table 3 - (continued) (See Map 2)

Area	Principal Functions/Description	Types of Waste (tonnes per day)				Total
		Commercial and Domestic	Industrial General	Agric. Food Processing	Other	
Sector E2	Urban support activity			10 (pigs)		13
Sector F	Plantation Agric.			50 (pineapples)		50
G	Plantation Agric.			20 (rubber)		20
H	Rice fields Market gardening			15 (rice husks)		15
I	Rice growing Market gardening	5		20 (rice husks)		25
TOWN C	Port Fishing Agric. Processing	46	260	41		347
Sectors						
C1	Depressed residential Markets	27		8 (pigs)		35
C2	Port related industry Commerce Residential	19	10	6 (fishing)		35
E3	Urban support activities			7 (pigs chickens)		7
J	Tin Mining		250			250
K	Plantation agric.			10		10
L	Rice fields Market gardening			10		10

Table 3 - (continued) (See Map 2)

Area	Principal Functions/Description	Types of Waste (tonnes per day)				Total
		Commercial and Domestic	Industrial General	Agric. Food Processing	Other	
TOWN D	Agric. Processing Centre Rural Service Centre	130		50		180
Sectors						
D1	Depressed residential Markets	22		15		
D2	Agric. Processing Residential	49		35		84
D3	Depressed residential	27				27
D4	Commercial Industrial Residential	32				32
E3	Urban support area			15 (pigs chickens)		15

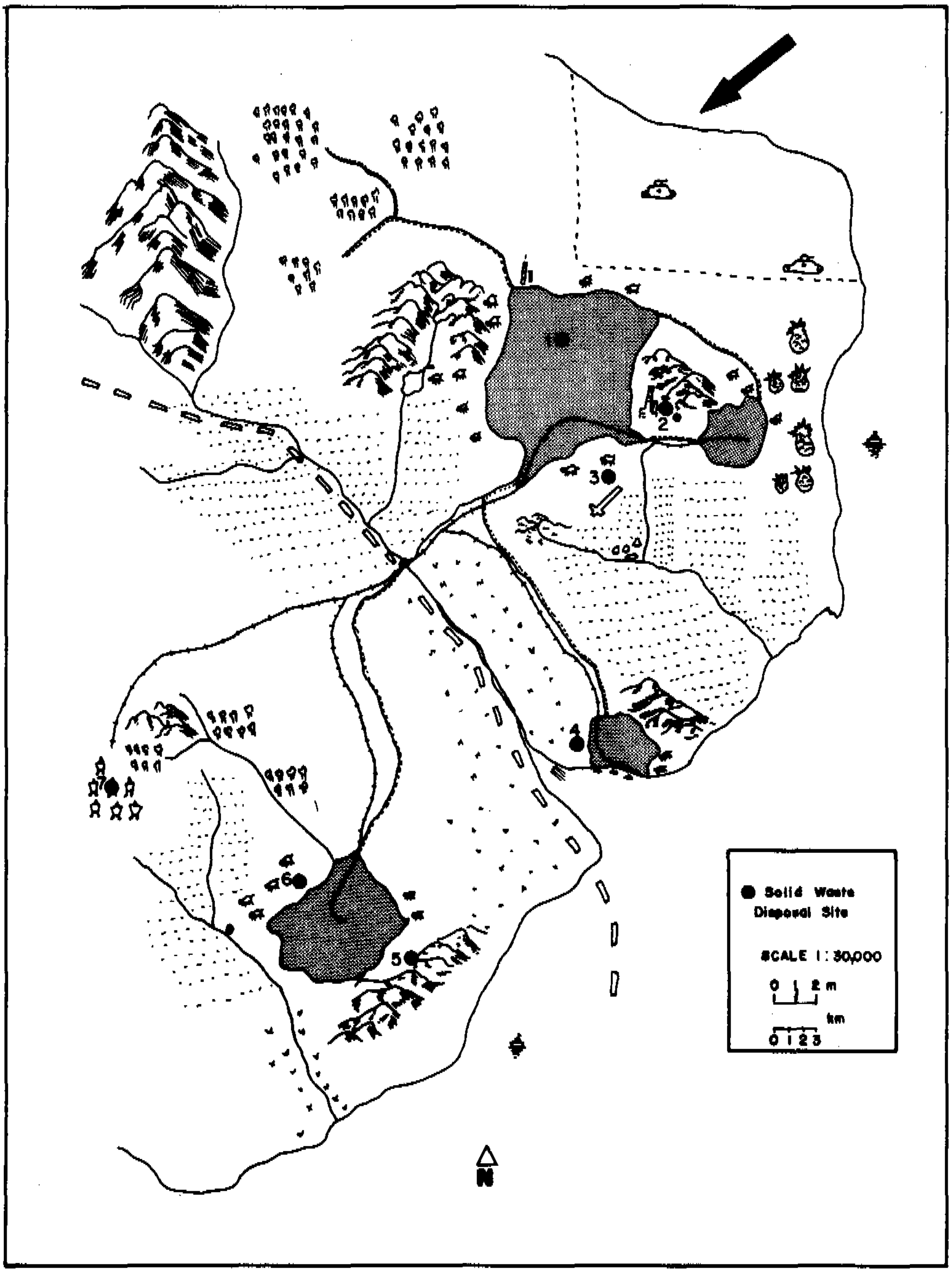
N.B. 1. Depressed residential waste generation: 1.0 lb/person/day (.45 kg)
Residential " " : 1.3 lb/person/day (.59 kg)

2. All figures are averaged over the year.

Table 4 - Existing Solid Waste Disposal Facilities 1978 (See Map 3)

Ref. No.	Description	Catchment Area	Capacity		Wastes currently treated/ tipped	Comments
			Existing Throughput t/day	Future Capacity		
1.	Compost plant. Compost sold for market gardening & for commercial potting.	A1, A2, A4	200 (max 380)		Commercial & Domestic	Site expansion is constrained by roads & residential development. Difficulties in finding markets.
2.	Landfill in disused quarry	A3, A5, A6 A7, A8, A9 B2	500	250,000 m^3	Commercial Domestic Agric. & Food processing.	Ground-water pollution increasing to unacceptable levels. Town is looking for new water supply.
3.	Landfill in natural depression	B1, A5, A8	50	200,000 m^3	Industrial Agric. & Food processing Excavation and Demolition.	May be beneficial for future airport extension.
4.	Landfill Swamp Reclamation	C1, C2	60	1,000,000 m^3	Commercial & Domestic Agric. & Food processing	Demand for land for Port industry expansion is strong. However lucrative oyster farms may be threatened by ground-water pollution
5.	Landfill. Old sand & gravel	D2 & D4	121	1,000,000 m^3	Commercial & Domestic Agric. & Food processing	
6.	Landfill in natural Depression	D1 & D3, E4	49	50,000 m^3	Commercial & Domestic Food processing & Agric.	Dumping organised to long-term golf course plan

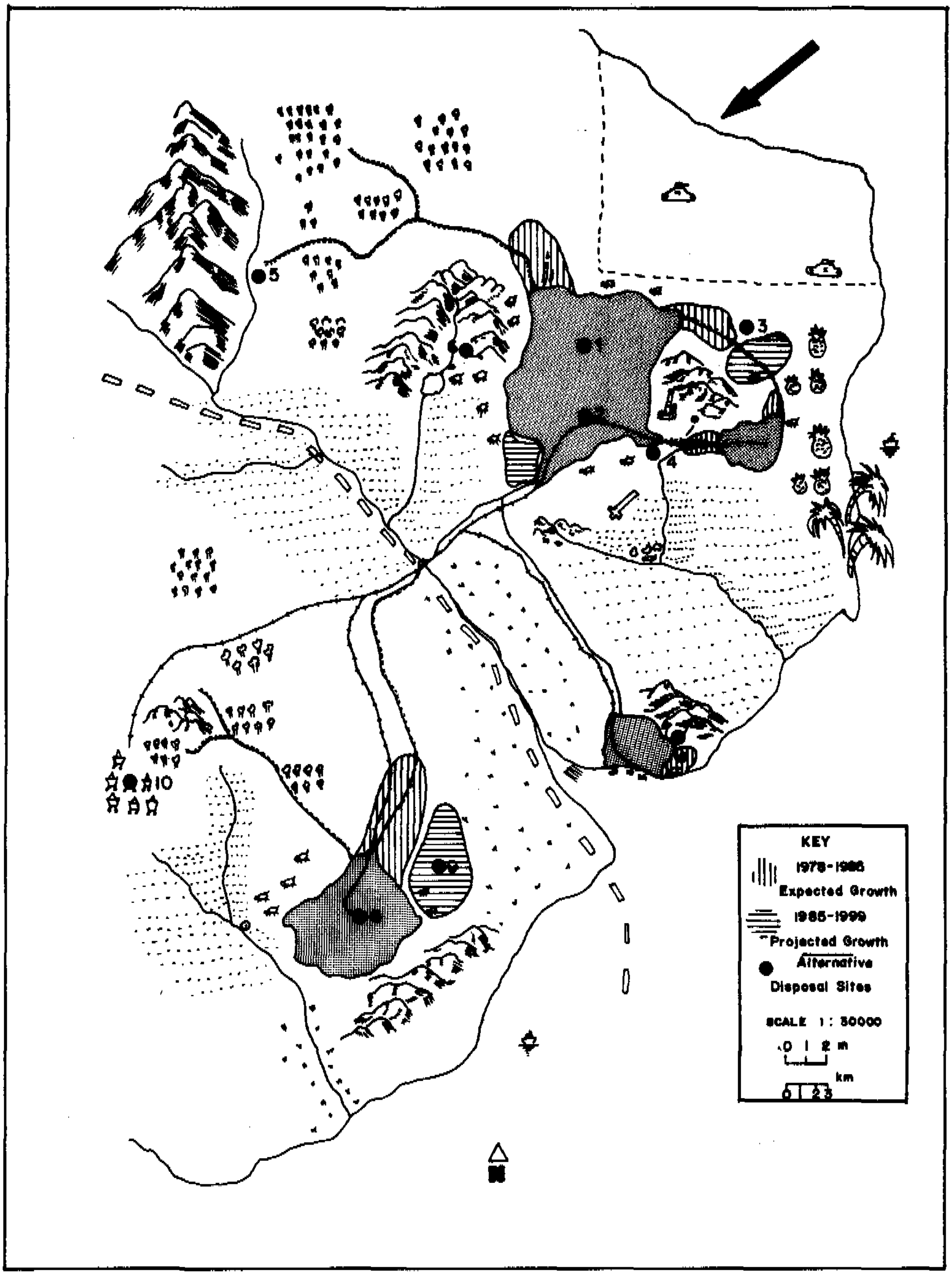
N.B. Agricultural and some industry wastes are regularly tipped on owners land and elsewhere with no planning consent.



MAP 3. ROWANNA SUB-REGION; DISPOSAL SITES 1978

Table 5 - Possible Future Disposal Options Available After 1980 (See Map 4)

Site Number	Description	Capacity	Problems
1.	Compost plant	380 tonnes/day	Old plant. Commercial viability questioned
2.	Council-owned site becomes available	8 acres (3.3 ha)	
3.	Landfill	550,000 m^3	Possible health threat to existing and future planned urban areas.
4.	Landfill	400,000 m^3	Fish farming and crop irrigation downstream becoming threatened from urban run-off and landfill ground-water pollution.
5.	Sand and gravel quarry	900,000 m^3	
6.	Landfill in disused quarry	600,000 m^3	Ground-water pollution threat to town's water supply.
7.	Landfill	370,000 m^3	Investors interested in developing high rise tourist complex on adjacent slope.
8.	Council owned site becomes available	6 acres (2.4 ha)	To assess merit of other demands for the site.
9.	Landfill	700,000 m^3	Smell nuisance and health threat (rats) to adjacent urban area.
10.	Tin mining quarry	12,000,000 m^3	Private owners



MAP 4. ROWANNA SUB-REGION; DISPOSAL SITES 1980

Table 6 - Analysis of Refuse

Component	Low Income Depressed Area %	Middle Income Area %	Higher Income Area %
Organic			
Paper and paper products.	7.2	27.2	22.3
Plastics	1.1	1.9	3.2
Other organics (vegetable and putrescible food waste, abattoir and animal waste; leather, rubber, yard waste, rags)	78.6	59.2	58.0
Inorganic			
Ferrous metal	4.7	3.7	6.6
Non-ferrous metals	-	0.1	0.1
Glass	2.7	2.1	5.4
Other inorganics (rock, concrete, earthenware, sand, ash, etc.)	5.7	5.8	4.4
	100%	100%	100%

WASTE HANDLING SUMMARY

The following paragraphs summarise information on collection and disposal methods.

Costs and operating factors (densities etc.) depend crucially on local conditions, types of waste etc. Therefore the figures included on the following pages, while providing a general guide, should not be used out of context.

COLLECTION

Density of waste: A density of around 0.2 tonnes per $metre^3$ may be assumed for domestic wastes in a standard vehicle. A compacting vehicle can give increased densities of 0.4 or more tonnes per $metre^3$.

Vehicles: Standard vehicle: Payload 4 tonnes; capital cost $ 17,500.

Compacting vehicle: Payload 7 tonnes; capital cost $ 37,500.

Costs per tonne of wastes collected: Standard vehicle: $ 35 per tonne; compacting vehicle: $ 25 per tonne.

TRANSFER HAULAGE

Density of waste: Density for bulk transport, depending on compaction process, can be assumed to be 0.5 tonnes per $metre^3$.

Vehicles etc.: Road vehicle : payload 18 tonnes; capital cost $60,000.
Rail, per wagon: payload 40 tonnes; capital cost of modification $25,000.
Rail, per train: payload 600 tonnes.

Cost per tonne: See Fig. 1 which assumes a density of 0.2 tonnes per $metre^3$.

PULVERISATION/SHREDDING

Density: Pulverised waste compacted for long-haul transport can achieve higher densities around 0.3-0.5 tonnes per $metre^3$.

Costs: 10 tonnes per hour (60,000 tonnes per year) including site works: capital cost $1M; 20 tonnes per hour (120,000 tonnes per year) including site works: capital cost $1.5M.

Including all site works for 90,000 tonnes throughput per year: cost per tonne $ 10.

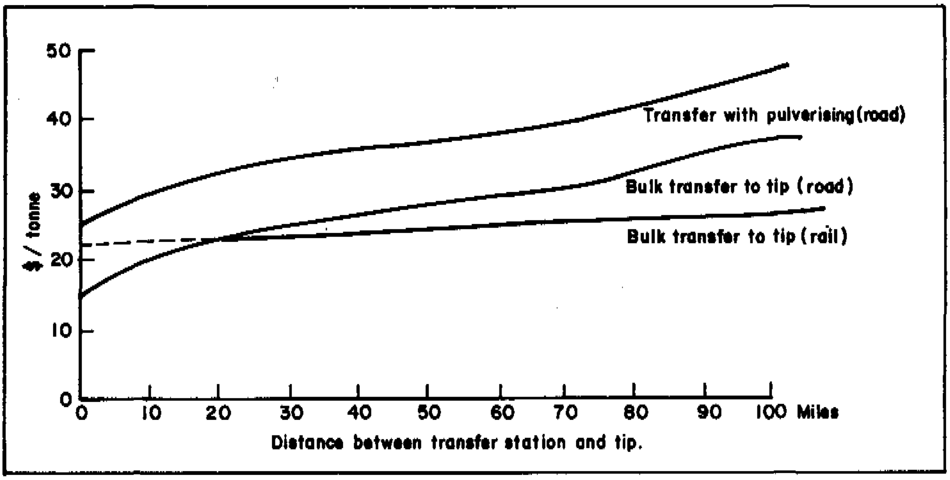


Fig. 1 - Transport Costs Including Cost of Transfer and Landfill

TRANSFER STATION

Costs: Rail transfer 400,000 tonnes per year: up to $ 8M; road transfer 100,000 tonnes per year: up to $ 4M, 400,000 tonnes per year: up to $ 6M.

Costs per tonne are included in the costs shown on Fig. 1.

INCINERATION

Reduction in weight etc.: Incineration should reduce weight of refuse by up to 80 per cent and volume by around 90 per cent. Actual reductions depend critically on composition.

Capital cost: 20 tonnes per hour (120,000 tonnes per year): capital cost $ 20M; 30 tonnes per hour (180,000 tonnes per year): capital cost $ 27M.

Excluding cost of tipping residue and assuming 6,000 hours operation per year, cost per tonne: $ 30M - $ 50M.

BALING

Density: Up to 1 tonne per metre^3. Transport cost can be reduced by one-third or more depending on permitted payload.

Costs: 20 tonnes per hour (120,000 tonnes per year): capital cost $ 3M.

Excluding cost of tipping and assuming around 6,000 hours operation per year the cost per tonne is $ 15M.

COMPOSTING

Costs: 40,000 tonnes per year: $3M; 150,000 tonnes per year: $ 10M.

Excluding disposal of residue etc. the cost per tonne is about $ 15M.

LANDFILL

Densities etc.: After 6 months: crude refuse 0.6 tonnes/m^3; pulverised refuse 0.75 tonnes/m^3; baled refuse 0.9 tonnes/m^3.

After 2 years: crude refuse 0.9 tonnes/m^3; pulverised refuse 1.0 tonnes/m^3; baled refuse 1.0 tonnes/m^3.

Costs

Site preparation costs vary enormously depending on requirements. For the case study, assume up to $0.8M per metre^3 for small sites (up to one million metres^3) and up to $0.4M for larger sites.

Costs per tonne for small sites are up to $15M while for large sites they are around $5-10M per tonne.

Resource recovery costs are summarised in Table 7.

Table 7 - Estimated Comparative Costs of Different Methods of Treating and Disposing of Household Wastes Plant to Handle 60,000 Tonnes Per Annum.

Treatment/ Disposal Method	Operating rate hours p.a.	Capacity needed tonnes/hr	Cost per tonne/ hr of capacity $ '000	Total capital cost $ million	Total gross operating costs $/t	Total net disposal cost/t of refuse $
1. Controlled landfill	2,000	35	71 - 214	2.5 - 7.5	5 - 15	5 - 15
2. RDF and ferrous metals recovery	4,000	18	333 - 472	6.0 - 8.5	21 - 28.5	9.5 - 17
3. Incineration with heat and ferrous metal recovery	6,240	12	1,458 - 1,875	17.5 - 22.5	50 - 60	41.5 - 51.5
4. Pyrolysis and ferrous metals recovery	6,240	12	108 - 2,291	17.5 - 27.5	55 - 80	27.5 - 52.5

PART II

PARTICIPANTS' PAPERS

CONTROLLED TIPPING IN HONG KONG

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INTRODUCTION

Hong Kong is located on the southeast coast of China and lies just inside the tropics, less than 160 kilometres south of the Tropic of Cancer. It has a land area of approximately 1,049 km^2, of which 740 km^2 are on the mainland. The Hong Kong Island and other adjacent islands make up the remaining area. The total population is about 4.5 million, the bulk of which inhabits the metropolitan areas of Hong Kong Island and the southern peninsula of the mainland. The population density (persons per km^2) varies between 25,400 in the urban areas to 550 in the northern part of the mainland known as the New Territories. These figures are, however, rapidly changing with the fast development of many new towns in the New Territories and significant redistribution is now being achieved.

SOLID WASTE GENERATION

Currently, some 4,700 tonnes of solid waste are generated daily in Hong Kong from the following main sources:- (i) Households, offices and shops (Domestic waste). (ii) Factories and trade premises (Industrial waste). (iii) Construction industries (Construction waste). (iv) Special industries, which include agricultural wastes, industrial effluents and sludges and toxic wastes (Special waste).

COLLECTION AND TRANSPORTATION

In Hong Kong household refuse is taken by occupiers of the premises to collection points where it is loaded into collection vehicles which call at these points at scheduled times. The vehicles are operated by the Urban Services Department and have capacities ranging from 1 tonne to 6 tonnes. The smaller ones are deployed to serve areas with congested roads and at short distances away from disposal points. Some of the vehicles are equipped with cutting-shearing-shredding teeth and a compacting mechanism. Any bulky waste can therefore be broken down and

Table 1. Sources of Solid Waste

Type	Tonnes/day	%
Domestic waste	2,600	55.3
Industrial waste	1,450	30.8
Construction waste	350	7.5
Special waste	300	6.4
Total	4,700	100.0

It can be seen from Table 1 that domestic waste constitutes by far the major share of the total solid waste generation. A typical analysis of its contents is shown in Table 2.

Table 2. Typical Analysis of Solid Wastes

	New Territories %	Kowloon %	Hong Kong Island %
Metal	9.24	1.92	2.17
Glass	13.71	4.86	9.72
Wood & Cinder	1.84	3.85	2.22
Dust & Fine Particles	0.45	25.04	14.09
Bamboo Basket, Junks	0.48	0.94	2.74
Vegetable Putrescible	21.69	4.35	9.07
Paper	15.55	16.31	32.46
Rag & Cotton Wastes	9.30	7.84	9.58
Plastic	15.39	10.55	6.24
Tannery & Slaughter Wastes	0.54	3.19	0.35
Unclassified Debris	5.39	20.77	10.47
Total	93.58	99.62	99.11

Note: The analysis was by actual weighing of each constituent. The fact that the recovered weight is less than 100% is due to loss of fine particles and mositure content during the course of test.

compacted so as to achieve a better payload for transportation to the final disposal point. The vehicles are operated daily on two 8-hour shifts and longer hours if demand arises. This service is provided free of charge by the Urban Services Department.

For industrial waste, up to 3.25 ft^3 (0.09 m^3) from each premises is removed free of charge by the Urban Services Department. For quantities exceeding this, the occupier of the premises is required to make his own arrangements for delivery of the waste to approved disposal points.

Construction waste, consisting mainly of building rubble and debris, is normally taken by contractors to approved dumps where the waste is accepted as filling material for land reclamation. Small quantities are accepted at controlled tips for construction and surfacing of access roads.

The majority of special waste is pig and poultry manure and generated in the New Territories where farmers live. There is no provision by the Government to collect this agricultural waste as most of it is used by the farmers as fertilizer. Other types of special waste is collected by arrangement.

DISPOSAL

Prior to 1966, disposal of refuse in Hong Kong was carried out mainly by tipping at designated dumps without any form of treatment apart from the final covering up by a blanket of earth. In 1966 the first incinerator with a capacity of 710 tonnes per day was installed on Hong Kong Island and treatment of solid waste introduced. Two years later a second incinerator with a capacity of 1,010 tonnes per day was installed on the Kowloon Peninsula. Meanwhile, a third one with a capacity of 910 tonnes per day is under construction in the New Territories and will begin operations this year.

While incineration still remains the preferred method of refuse treatment in Hong Kong because of its high volume reduction (10 to 1), increasing difficulty is experienced in gaining acceptance for incinerator sites due to visibility and atmospheric pollution objections. High capital and recurrent costs are also negative aspects in the choice of treatment methods.

In view of the limitations of incineration, a study was conducted by the Public Works Department in 1971 on the treatment of refuse by 'controlled tipping', otherwise known as 'sanitary landfill', which would offer the double attraction of lower costs and the production of recreation land. After establishing suitable sites, the technique was first introduced in June 1973 on a site at Gin Drinkers Bay on the Kowloon mainland. The experience on this first controlled tip has proved to be highly successful and many other sites were selected subsequently for such use. At present there are 4 sites in operation, receiving a total of some 2,520 tonnes of refuse daily. Further sites are being planned for. Fig. 1 shows the various completed and planned sites.

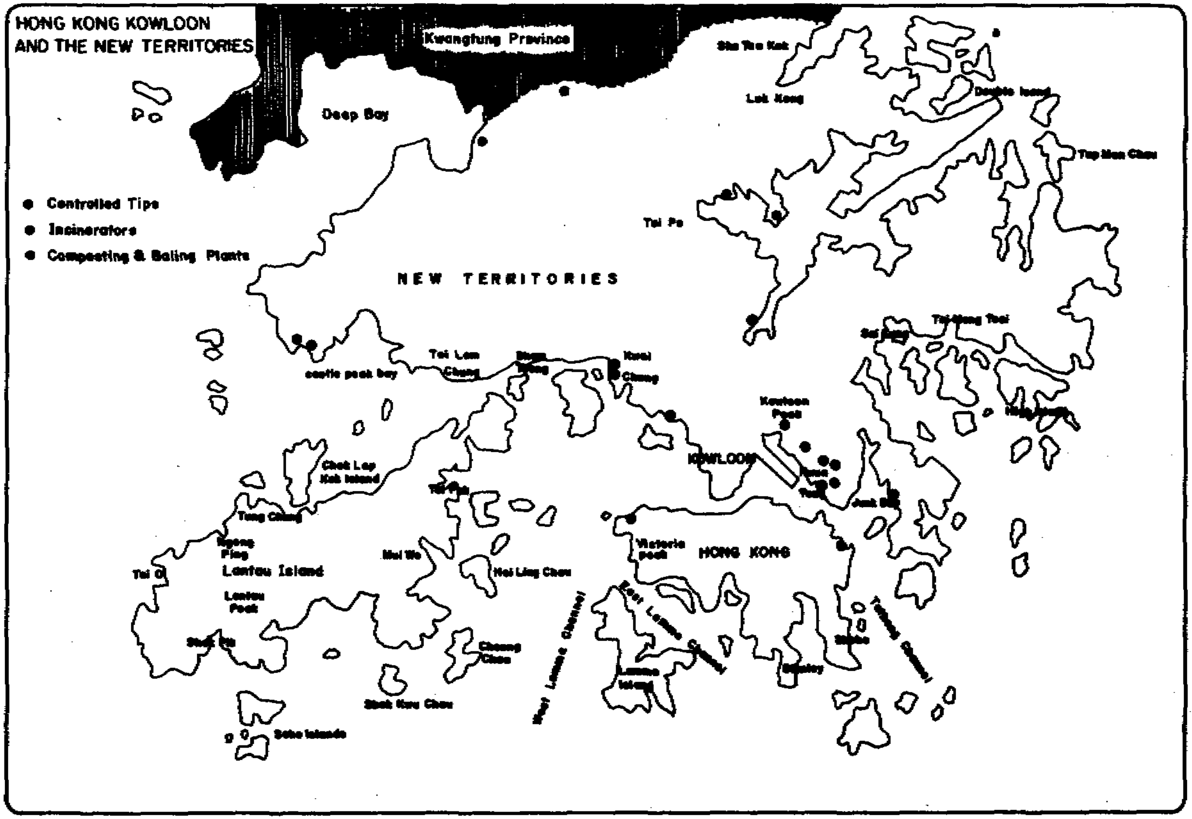

Fig. 1. Location of Solid Waste Disposal Systems

Other methods of solid waste treatment have also been investigated and construction is in progress for a pulverisation/composting plant on Hong Kong Island and a pilot baling plant on the mainland. The former, at an estimated cost of HK$47.5 million (US$9.83 million) has been designed to an initial capacity of 240 tonnes/day capable of extending to 480 tonnes/day with a refuse bulk reduction ratio of about 4 to 1. The compost will be used as a covering material for controlled tips or for agricultural purposes. Operations were scheduled to commence in February 1979. The baling plant, at an estimated cost of HK$16 million, has a treatment capacity of 600 tonnes/day with a refuse bulk reduction ratio of about 5 to 1. The finished bales, which are about 1.5 m^3 in volume, will be transported to controlled tips for disposal. The plant was in operation at the end of last year. Plans are also in hand to construct a second composting plant at Sha Tin in the New Territories.

Table 3 gives the average daily quantities of solid waste disposed by the present 2 methods.

Table 3. Average Daily Quantities of Solid Wastes Incinerated and Tipped

	By incineration (tonnes)	By controlled tipping (tonnes)
Domestic waste	1,000	1,600
Industrial waste	550	900
Construction waste	-	-
Special waste	-	20
Total	1,550	2,520

METHOD OF CONTROLLED TIPPING

The method now practised in Hong Kong requires fresh refuse to be spread and compacted in layers by a mechanical plant to a maximum consolidated thickness of 2 metres. Proper compaction of the deposited refuse is essential for achieving maximum volume reduction as well as for minimising hollow spaces where vermin can hide and nest. This is then covered with earth filling or other suitable materials to a thickness of 0.25 metre and again compacted by mechanical means. All working faces are also sealed off by earth filling immediately at the end of each shift or at the conclusion of each day's work, whichever is the earlier. The compacted refuse is thus confined to a number of earth 'cells', the size of which can be predetermined to accommodate quantities of waste delivered daily on site. This method makes a striking difference between an open refuse dump and a controlled tip. The compacted earth eliminates the necessary air supply for animal survival, prevents the emergence of insect larvae, reduces the attraction of birds to the refuse and discourages rodents from scavenging for food. It also prevents waste from being blown around, seals off odour and gases and lessens fire hazards from the spread of internal combustion.

Fig. 2. shows a diagrammatic illustration of the typical operation.

Problems

Wet weather seriously impedes plant manoeuvrability. Adequate site drainage and all-weather access roads are therefore essential in the effective operation of controlled tips. Broken concrete and building debris is often used as temporary surfacing material for these access roads which are varied continuously to suit the changing layout of tipping bays. This results in higher maintenance cost of the compaction and earthmoving plant and delivery vehicles due to heavier wear and tear.

However, under dry weather conditions the process of excavation, hauling and placing of cover materials is a substantial daily operation which on unsealed access roads gives rise to a major dust problem. It is essential that periodical water sprinkling be maintained. Fences or screens may also be used to help control dust.

Refuse is particularly conducive to spontaneous combustion. Experience has shown that fires tend to break out generally during the early hours of the morning when supervision is necessarily at a minimum. These fires often continue to burn for long periods. Careful control must therefore be exercised in ensuring proper compaction of refuse and the prompt use of emergency stockpiles of cover materials which must be ready on site at any time.

Odorous gases are products of surface putrefaction of deep-anaerobic digestion. These can be prevented by prompt and continuous covering, elimination of surface pools, side leaching action and seepages at the toes of filled embankments, the sealing of surface cracks and by spraying the refuse with suitable deodorants.

A potential source of water pollution arises from leachate, an effluent produced by surface water infiltrating through the refuse and by decomposition of solid waste. It must therefore be properly controlled to avoid contaminating underground water. On controlled tipping sites in Hong Kong this is achieved by the installation of an impervious membrane liner on the prepared floor of a tipping bay and the laying of a network of sub-soil drains to intercept and collect the leachate into chambers where it is biologically filtrated before being discharged into sewers.

Details of sub-soil drains appear in Fig 3.

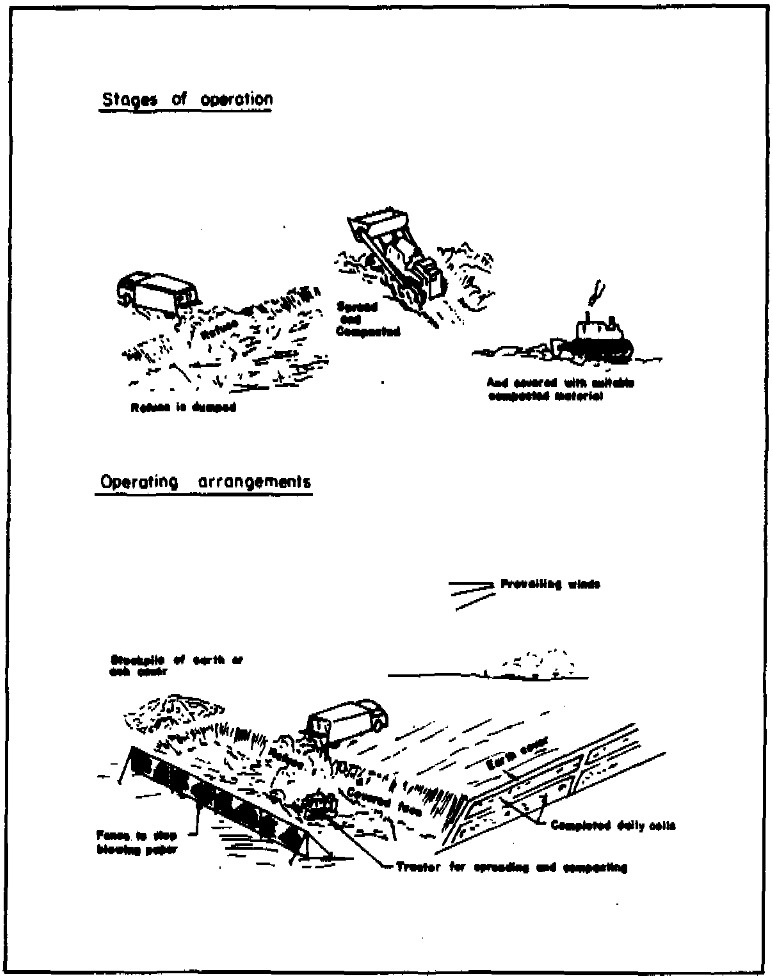

Fig. 2. Diagrammatic Illustration of Controlled Tipping

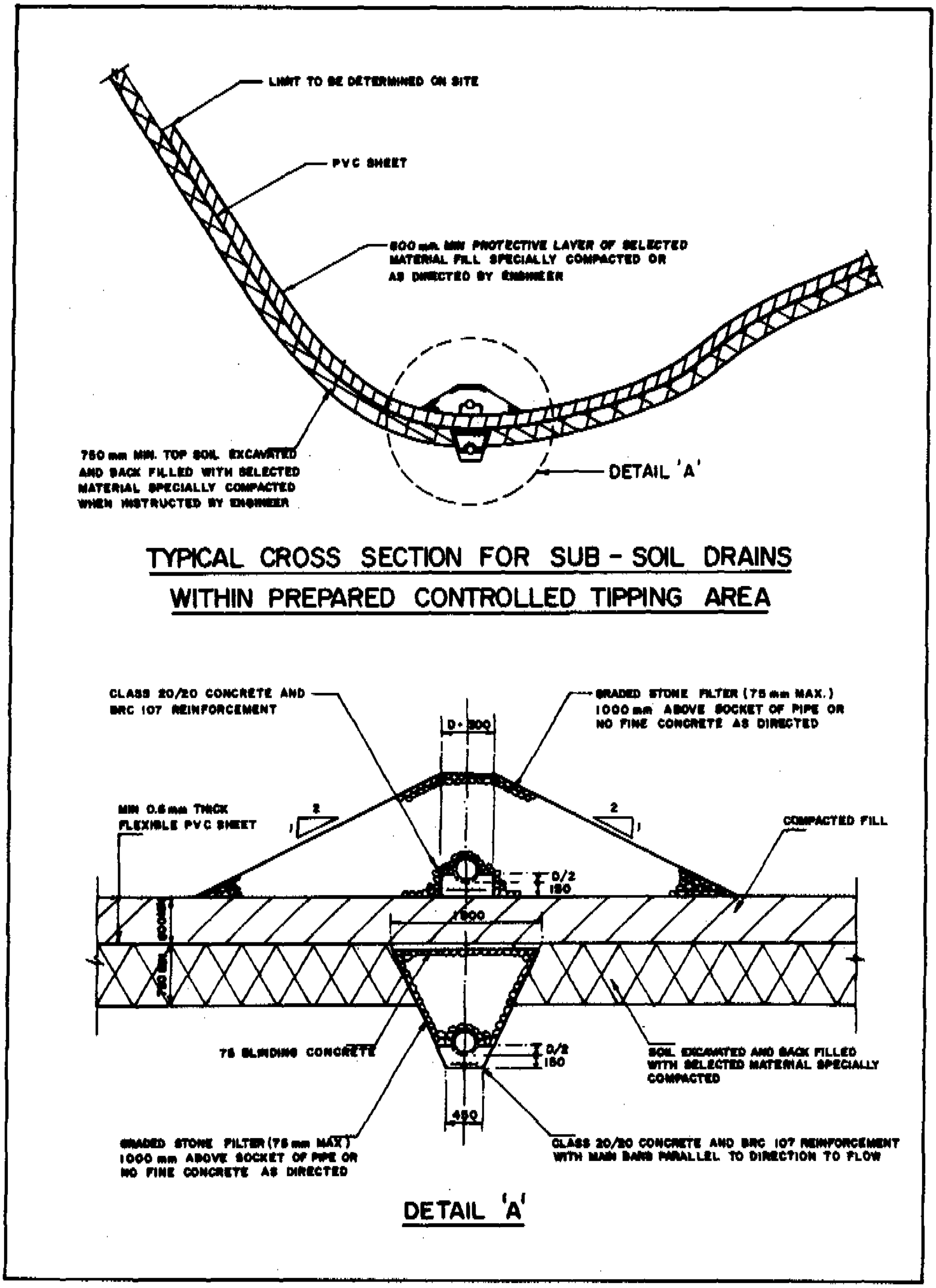

Fig. 3. Typical Cross Section for Sub-Soil Drains
Within Prepared Controlled Tipping Area

COST

The cost of controlled tipping varies widely from site to site. The main variables are land acquisition, site clearance and preparation, operation, the availability of covering material, and landscaping.

Because of the shortage of land in Hong Kong, land acquisition and subsequent clearance are becoming more expensive. The problem is further aggravated by frequent opposition from local villagers and often requires payment of heavy financial compensation.

Site preparation and operation costs can be estimated with some accuracy for a given site. These costs increase substantially for remote sites, but to a certain extent tend to be economically offset by the land acquisition and clearance costs. Experience in Hong Kong has shown that in general the larger the capacity of the site, the lower the unit cost will be.

Covering material can be quite expensive if it is to be obtained from borrow areas where additional land and landscaping costs are required. Wherever possible, the material should be obtained from nearby site formation projects where surplus excavation is available.

Table 4 shows unit costs and other particulars of various controlled tips in Hong Kong — both those completed and under planning.

Approximate unit costs, excluding that for land, of various treatment methods appear in Table 5.

FUTURE PLANNING

The total quantity of solid waste requiring disposal each year depends on population growth and distribution and the per capita rate of solid waste generation.

The rate of solid waste generation is affected by the prevailing standard of living and consuming habits and the trend and form of commercial activities and industrial development.

From data collected over the past years and by reference to available data from abroad, it is evident that the solid waste generation rate per capita is increasing. It is possible that an increase in effort on the part of the collection authorities may contribute to a significant portion of this growth rate. Over an eight-year period from 1963, the rate of solid waste generation for Hong Kong Island showed an average of approximately 0.27 kg/head/day. But this rose sharply to 0.63 kg/head/day for the period 1971 to 1973. From 1974 to 1977 it was 0.73 kg/head/day. The corresponding figures for Kowloon and the New Territories were on the whole about 0.08 - 0.16 kg/head/day higher due to more intensive industrial development and low-cost housing estates.

Table 4. Unit Cost and Other Particulars of Various Controlled Tips

Site	Estd. Cost (HK$m.)	Capacity (m. tonnes)	Unit Cost (HK$/tonne)	Tipping Commenced	Life Expectancy	Level area formed and proposed use (ha.)	Remarks
Gin Drinkers Bay	16.00	2.30	5.94	June 1973	67 months	23.0 ... 2 artificial hills 4.7 ... open space	Previously an open dump converted to controlled tip in 1973.
Ngau Tam Mei (completed)	1.30	0.03	43.30	Dec. 1973	15 months	1.0 ... open space	Substantial preparation work carried out.
Shuen Wan	15.60	0.66	23.64	June 1974	8 years	5.5 ... open space 3.0 ... undetermined	
Ngau Chi Wan	12.00	0.63	14.46	Jan. 1976	22 months	4.5 ... open space 2.2 ... cultural	
Ma Tso Lung	4.35	0.15	29.00	July 1976	28 months	2.0 ... open space	Expensive clearance costs.
Sai Tso Wan	20.50	1.70	12.06	Mar. 1977	34 months	2.2 ... open space 2.4 ... stadium 1.5 ... educational	
Shiu Lang Shui	17.66	0.53	33.30	Sept. 1978	5 years	3.8 ... open space 0.5 ... undetermined	Long road access required.
Ma Yau Tong West	24.29	0.80	30.35	Oct. 1978	24 months	3.0 ... open space 1.8 ... cultural	High clearance costs.
Junk Bay Stage I	101.00	6.00	16.84	end 1979	7 years	25.0 ... 2 artificial hills 8.2 ... residential	
Ma Yau Tong Central	28.51	0.80	35.60	mid 1980	30 months	4.7 ... open space 1.1 ... cultural	High clearance costs.
Jordan Valley	44.00	1.40	31.45	1982	4 years	8.2 ... open space	Expensive reprovision works.
Yim Tin Tsai	134.00	7.40	18.10	1982	over 10 yrs.	undetermined	
Pillar Point Valley	37.50	1.25	30.00	1983	5 years	14.4 ... open space	Long road access required.

Table 5. Unit Cost of Various Treatment Methods

	HK$ per tonne
Incineration	48
Composting	40
Controlled tipping	22
Baling (excluding disposal)	17

There are indications that solid waste generation in Hong Kong tends to increase at a much slower rate. Although the effect of increasing industrialisation cannot be predicted with any accuracy, it may generally be anticipated that rising costs of both raw materials and production will cause manufacturers to become more economical in their use of products and that waste generation will become less viable.

On the domestic side, the local standard of living and consuming habits have to a certain extent started to become less oriental. For instance, the strong preference in the past for recently-slaughtered meat and fish and for very fresh vegetables has weakened due to significant increases in the import of frozen meat and vegetables. This, on the whole, reduces the domestic waste generation rate considerably.

However, for the purpose of planning after taking into due consideration the available data, a flat growth rate of 6 per cent per annum has been taken in the preparation of 10-year planning programmes for Hong Kong Island. The corresponding rate for Kowloon and the New Territories is 6.5 per cent. It is acknowledged that these may yield upper bound figures, but it is considered advisable to plan for the higher levels and to update the programmes regularly as data collection continues and more accurate information comes to hand.

The current 10-year programme for the period 1977-86 on solid waste generation forecast and disposal capacities are given in Tables 6 and 7.

CONCLUSION

Controlled tipping is an effective and economical means of solid waste disposal which is environmentally acceptable. There are operational problems, but these are not insurmountable. It becomes more attractive as additional land is formed even though there are limitations on the land use.

It is, however, becoming more difficult to find suitable sites which must be acceptable to the public as well as being economically

Table 6. Solid Waste Generation Forecast

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
H.K. Island Generation Rate (kg./head/day)	0.73	0.77	0.82	0.86	0.91	0.95	0.99	1.04	1.08	1.13
Solid Waste requiring disposal (tonnes/day	790	837	885	932	980	1027	1074	1122	1169	1217
Kowloon and N.T. Generation Rate (kg./head/day	0.88	0.94	0.99	1.05	1.11	1.17	1.22	1.28	1.34	1.39
Solid Waste requiring disposal (tonnes/day)	3020	3216	3413	3609	3805	4002	4198	4394	4590	4787
Total (tonnes/day)	3810	4053	4298	4541	4785	5029	5272	5516	5759	6004

NOTES: Population projections are based on 1975 forecast and construction and special wastes are excluded.

viable. High density baling, which is an interim treatment, is therefore being adopted to maximise the tip capacities.

Notwithstanding the advantages of controlled tipping, it is to be recognised that the continual generation of solid waste will one day fill up all available sites in Hong Kong and the demand is apparent for a greater use of incineration in the future.

Table 7. Solid Waste Disposal Capacities in Tonnes per Day

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Incinerators										
Kennedy Town	610	710	710	710	710	710	710	710	710	710
Lai Chi Kok	760	1010	1010	1010	1010	1010	1010	1010	1010	1010
Kwai Chung	-	290	910	910	910	910	910	910	910	910
Total	1370	2010	2630	2630	2630	2630	2630	2630	2630	2630
Compost										
Chai Wan	-	-	150	240	480	480	480	480	480	480
Sha Tin	-	-	-	300	480	480	480	480	480	480
Total	-	-	150	540	960	960	960	960	960	960
Controlled Tips										
Gin Drinkers Bay	410	100	-	-	-	Exhausted		-	-	-
Shuen Wan	60	200	200	220	230	280		Exhausted		
Ngau Chi Wan	680	-	-	-	Exhausted			-	-	-
Ma Tso Lung	180	200	-	-	Exhausted			-	-	-
Sai Tso Wan	1110	1400	1100	330	-	Exhausted			-	
Shiu Lang Shui	-	100	200	200	230	300	450	Exhausted		
Ma Yau Tong & Jordan Valley	-	50	150	230	200	200	250	360	410	510
Junk Bay	-	-	50	540	1000	1250	1370	1830	2240	2490
Yim Tin Tsai	-	-	-	-	-	50	420	420	420	510
Pillar Point Valley	-	-	-	-	-	-	50	400	400	500
Total	2440	2050	1700	1520	1660	2080	2540	3010	3470	4010
Grand Total	3810	4060	4480	4690	5250	5670	6130	6600	7060	7600

COUNTRY REPORT: INDONESIA (JAKARTA)

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INTRODUCTION

Speaking of the present solid waste management of Jakarta within the context of city problems such as its establishment, its rehabilitation or development, we have to first observe the location of the city, the nature of its administration as well as the living aspirations in the city itself.

The city of Jakarta has an area of 560 km^2 excluding many small islands in the bay of Jakarta. Geographically, it is part of West Java's northern coastal plains, stretching 60 km long and 28 km wide where 10 rivers and canals flow northwards. These rivers and canals a are also important for the irrigation of ricefields around Jakarta.

The city itself is bordered to the North by the Java Sea, to the East by the Cakung River, to the South by the District of Bogor and to the West by the Angke River.

The highest land in this area is found in the southernmost part and averages only 50 metres above sea level. The northern part is mainly swamp.

Topographically, Jakarta can be divided into 2 distinct parts — north and south of the Banjir Kanal (flood control canal).

The northern part is bordered by the sea and rivulets of the Banjir Kanal. It is approximately 10 km wide and reaches a maximum height of 5 metres above the zero point of Tanjung Priok.

This is very much in contrast with the conditions to the south of the Banjir Kanal. It is a relatively hilly area, with a higher gradient than the Northland rising from 5 to 50 metres for the 18 km length of this part. So it can be said that this southern part is relatively steep, while the northern part is nearly flat.

The hot, tropical climate of Jakarta has a high rate of relative humidity (80 to 90 per cent) with an average daily temperature of 30 Celsius. Due to its location in the equatorial zone, Indonesia and the city of jakarta itself are under the influence of the monsoons; from November to April being affected by the West monsoon and from May to October by the East monsoon. Jakarta is also subject daily to land and sea breezes blowing alternately northwards and southwards.

The average annual rainfall is 2,000 mm and the maximum rainfall is usually in January.

POPULATION

The population growth of Jakarta was very rapid after the Second World War. In 1972 total population was 4.3 million including 138,000 foreigners. The rate of growth for the period 1961-1971 is estimated at 5.7 per cent annually, 2.5 per cent being due to natural growth (difference between birth and mortality rates) and 3.2 per cent caused by urbanisation. Compared with other big cities in Asia, Jakarta has the highest population growth.

Jakarta, as a big city as well as the capital of the Republic of Indonesia, plays its role as a place which handles all kinds of national activities and development. It has thus been a powerful magnet attracting people from suburban and rural areas. Construction work and development undertaken in Jakarta has provided attractive job opportunities and many people from outside the city and from rural areas are flooding the city. Moreover, the availability of educational facilities, health services, communications and recreation facilities have also intensified the urbanisation process.

Urbanisation is due to various reasons. Formerly it was due to insecurity in certain rural areas but now the emphasis is more on economic and social reasons.

As for the city itself, the urbanisation process does not only reflect the population increase, but also creates very serious problems.

Coming from traditional village communities with intimate personal relationships, urban residents comprising peasants and labourers arrive with high expectations. Stiff competition in finding jobs and other such unexpected urban socio-economic realities have become the sources of problems in the city such as crime, demoralisation and other kinds of urban vices.

The effects are obviously reflected by the presence of vast slum areas, potential sources of fires and epidemics.

In general, Jakarta has to fulfil 2 important roles:

As the capital, its role and activity should guarantee the preservation of national interests as can be evaluated from the activities performed within the country as well as foreign-related activities executed in Jakarta.

As a city playing a universal role, this should be really guided and public services and prosperity to its community should be provided.

These 2 roles should be complementary and parallel in their fulfilment and accomplishment.

Community life in Jakarta is somewhat different from those found in other cities in the country due to the existence of national and international aspirations requiring national as well as international considerations in addition to the efforts for the promotion of living conditions of the local populace.

Seeing to it that foreigners can adapt, in most cases, to our national way of life, we cannot, therefore, ignore the demand for civilisation or norms of international life.

Here lies the problem of Jakarta's administration. It must be able to provide balanced public services to meet the 2 somewhat different ways of life with the limited facilities available. Meanwhile, traditional ways of life are noticeable in the capital which are in fact opposing the instinct of dynamic city life dominated by logical ways of thinking and modern development.

There are efforts being made in Jakarta to promote and speed up the growth of dynamic thinking towards modernisation and a wide understanding which might soon create the norms of city life.

The warm climate and the dense population make Jakarta a city which can easily become dirty. The heat causes organic substances to get rotten easily. Combined with heavy dust, this poses a big challenge for sanitation authorities.

The efforts taken by Jakarta's administration in this field will have no meaning if the population is not aware of the importance of city health. Therefore, to imprint this responsibility on its population, Jakarta's administration is striving to induce them to participate in maintaining the city's hygiene by making them realise that their active participation means improving their environment.

The efforts in city clearing, particularly in solving the problem of wastes in Jakarta, is undertaken by the Cleaning Service with its scattered units. The implementation of a decentralised policy in solving this problem has been extended to each family in the community under the co-ordination of the local village head. For this purpose the service has improved its equipment and means of transportation.

It is important to know that the special Territory of the Capital City of Jakarta is designated as a first grade region or province level, similar with any other first grade region in the country. The head of the region conducts the administration and is responsible to the President through the Minister of Home Affairs in accordance with the existing hierarchy. The governor, in addition to his function as head of the autonomous region, also acts as representative of the central government in the region. The region's administration maintains structurally, procedurally and operationally an integrated staff unit of the central Government with the autonomous administration of DKI Jakarta administration on the basis of "functional integration" so that a single administration system is performed in accordance with the spirit and content of the Presidential Instruction No. 05, 1967.

Generally, the governor is responsible for the whole region's administration. The deputy head of the region, as assistant to the head of the region, is responsible to him. The municipal secretariat, as the general staff of the municipality, consists of 8 directorates and 7 bureaux co-ordinated by the executive secretary. The directorate is assigned to handle the main duties of the administration (major executives) and the bureau provides auxiliary services.

The core of the executives consist of the mayor/administrative township head with the local/central agencies/local public corporations as their special staff.

Within the context of rendering services to the community to conform with the duties of a socially-oriented administration, the region's administration is carrying out a deconcentration programme. The territory is divided into 5 administrative entities, i.e. Jakarta Pusat (Central), Jakarta Barat (West), Jakarta Utara (North), Jakarta Timur (East) and Jakarta Selatan (South). It is also divided into 5 town territories, 30 subdistricts and 236 villages. The village administrations are subordinate to the subdistricts. The village head in DKI Jakarta is a government official whose appointment is made by the governor/head of region.

The district chief is the head of the subdistrict and is responsible to the mayor with regard to the administration in his territory. With the purpose of maintaining and promoting closer ties between the administration and the public and as a response to the healthy public participation, community and family associations have been reorganised. The aforementioned overall reorganisation of the region's administration is meant to improve and expedite services to the public.

JAKARTA CITY CLEANSING DEPARTMENT AND ITS PROBLEMS

Responsibility

On the issuance of Jakarta Governor's Decision No. Db. 4/1/7/1967, dated December 6, 1967, on the formation of Jakarta City Cleansing

Department, all responsibility for cleanliness of the Jakarta area was instantly turned over to this department. Following the growth of urban areas experienced by Jakarta, the Cleansing Department's responsibility became greater and more extensive. As explained earlier, it is obvious that the more populous Jakarta becomes the more voluminous the wastes will be.

Fortunately, the main task conducted by this agency is still limited to the solid waste problem because other types of pollution are insignificant in comparison.

Nevertheless, the Cleansing Department has realised that its responsibility will be increasing in the future. Water and air pollution has become visible in the Jakarta area and will be a challenge which requires the awareness of the agency.

In this context, the Cleansing Department is making all efforts to consolidate and prepare itself for operations relevant to the growth of a modern, efficient and effective city administration.

Organisation and Operational Pattern

Since its establishment until now, many changes and improvements have been experienced by this department, either to its organisational structure or operations following the improvement of the Jakarta city administration.

City growth has caused new changes and improvements to the organisational structure, government apparatus, in terms of personnel, facilities and finance.

The Cleansing Department's organisation is growing according to Jakarta's development. At present, this department has 12 people as core staff consisting of 1 chief officer, 2 deputy chiefs and 9 division heads. There is 1 chief of a sub-department in each of the 5 administrative regions. Up to now, there are 29 cleanliness inspectors in the sub-districts and 125 superintendents in the communities (kelurahan).

The Cleansing Department still stresses the traditional labour intensive approach where the human factor is always given priority.

It is not surprising, then, that due to increasing work volume, the number of workers is also increasing. When the department was established, there were 4,546 personnel. Ten years later in 1977, the staff totalled 7,211, including administrative personnel and operators, see Table 1.

The staffing policy of the Cleansing Department is represented in Tables 2 and 3.

Table 1. Personnel Growth of the Cleansing Department (1967-1977)

Year	Number of employees
1967	4,546
1968	4,546
1969	5,312
1970	5,558
1971	5,859
1972	6,107
1973	6,363
1974	6,363
1975	6,363
1976	7,211
1977	7,211

Table 2. The Staffing of the Cleansing Department

Head office staff	1,281
Central Jakarta Sub-department staff	2,648
North Jakarta Sub-department staff	623
West Jakarta Sub-department staff	1,020
South Jakarta Sub-department staff	851
East Jakarta Sub-department staff	788
Total	7,211

Table 3. Details of Assignments

Sweeping operators (road sweepers)	4,362
Truck/Cart operators (driver and crew)	1,772
Workshop (transportation maintenance)	159
Waste utilisation/disposal areas	103
M.C.K. operators	24
Pump of excretas operators	128
Cleanliness Supervisors (Special Police)	378
Administrative Works	285
Total	7,211

Based on the decision of Jakarta Governor dated September 2, 1972, No. Jb. 4/2/45/1972, 200 special policemen were appointed to the Cleansing Department as non-salaried staff on February 20, 1973. The chief of the department, in his letter dated December 20, 1972, assigned them to each sub-department as follows:

- Central Jakarta Sub-department	25
- North Jakarta Sub-department	21
- East Jakarta Sub-department	15
- South Jakarta Sub-department	20
- West Jakarta Sub-department	15

The total number of special policemen of the Cleansing Department is 247 men, "Prajaksa" 15 men.

CLEANSING DEPARTMENT OPERATIONS AND MANAGEMENT

Discipline

Cleansing discipline is a situation where environmental quality in every aspect is well-maintained and protected from pollution.

In promoting this, 2 kinds of activities are performed simultaneously.

Firstly, Jakarta's Cleansing Department functions in such a way that all wastes are disposed of on time and the proper methods are used.

Secondly, the source of pollutants is monitored, controlled and regulated. This programme is conducted through good communications, information, guidance and training complemented with legal sanctions.

The implementation of these programmes are reflected in the operational techniques performed by the Cleansing Department. Should these programmes be well executed, then cleanliness discipline in a real sense will be a reality.

Operational Techniques by Region

The person responsible for solving the cleanliness problem in each municipality is the respective chief of the sub-department office which is directly under the guidance of the mayor concerned. He is also under the guidance of the Jakarta Cleansing Department administratively.

The relationship between the head office, branches (sub-department), inspectors and the superintendant is functional while the relationship between the mayor, sub-department, sub-district heads, supervisors, village heads and cleanliness inspectors is the line of command (operational).

In view of the above directives, employees of the cleansing Department assigned to a municipality including all the department's equipment such as trucks and carts are under the mayor's authority. Therefore, each mayor, as head of the municipality, has the authority to mobilise and direct cleansing operations needed in his area at any time by deploying all available facilities.

Such delegation of authority will enable the head of the area to direct and control effectively cleanliness operations in his area.

From 1967 up to now, labour intensive activity is still functioning well in the field of waste collection by sweeping and transportation with trucks and carts.

The management of solving the waste problem requires adjustment with the development of Jakarta. It is clear that the operational management of the Cleansing Department should follow the development dynamics of the city in all aspects. Population growth, city facilities, the standard of living and industrial growth all require an improved working system because volume, type and the quality of the work itself is changing.

At each working area, either on important roads or others, employees of the Cleansing Department sweep, collect and load the wastes into the carts following them.

During its first years, the Cleansing Department was trying to find out and formulate an operational system adaptable to the cleanliness situation at that time. Heaps of waste along the streets could not be quickly removed by road sweepers while the problem of a shortage of transportation such as carts and trucks required an immediate solution.

The cleanliness inspector in each sub-district directly handles and manages sweeping work in his area both on the streets and near market places. Sweepers are supervised at the "kelurahan" (community) level by foremen. In 1973, the term "foreman" was changed to "cleanliness supervisor" who has authority and a definite assignment. Consequently, uniform cleanliness operations in each "kelurahan" has been achieved.

A department regulation prohibits waste diposal before 13.00 and in some important or business streets with heavy traffic sweeping is performed twice daily, first from 03.00 until daybreak and later from 15.00 hours. Nevertheless, the result is not as might be expected as the streets become dirty again as soon as the city comes to life.

Foremerly, there were some temporary dumps for waste such as those located at Tanah Abang I, Jembatan Serong, Lautze Street, and Karang Anyar Street near the Cideng river which were reserved for the community and marketplaces. These places have been gradually wiped out as they are not suitable anymore in the context of the city's development.

During 1969 and 1970, sweeping was improved by the formation of sweeping teams. Each team consists of an average of 10 people including 1 cart drawer.

Each team is responsible for the cleanliness of the area assigned to them considering the volume of daily waste in the area as well as the size of it. Simplification and improvement of the team's operation has increased manpower efficiency and they have been able to include those areas formerly without a sweeping team including rehabilitated villages.

In view of the improvement of city facilities, it is felt necessary that mechanisation in waste transportation needs improving.

Dealing with wastes derived from industries and other enterprises having chemical waste, producers are obliged to solve the waste problem and if necessary to minimise the degree of pollution.

Table 4. Waste Volume in Jakarta and that Disposed of by the Cleansing Department

Waste production		
From 5.2 million population at 2 lt/cp/day		10,400
Sectors performing self disposal		
Marketplaces		1,100/day
Some industries		900/day
Absorbed naturally in the village		500/day
	Sub-total	2,500
	Balance	7,900
Thus Volume Disposed of by the Cleansing Department		7,900

After making continuous observation for 3 months, wastes in Jakarta can be categorised by type and volume as in Table 5.

Problem of Disposal

All trucks operated by the department in Jakarta as well as carts operating nearby dispose of waste into open pits.

This is known as the open dumping system which, although inexpensive,

Table 5. Waste by Type and Volume

Type of Waste	Volume (Per Cent)
Paper	2.34
Plastic	3.17
Waste from kitchen (Organic material)	81.85
Various shells, egg shells, etc.	5.23
Metal	3.24
Glass	0.40
Sand, soil, crushed sonte	3.31
Total	100.00 (100%)

is not appropriate from a sanitation point of view since secondary pollution such as air pollution (bad smell), fire hazards and health hazards such as typhus, dysentry and cholera will arise.

As practised today, open dumping at certain places in Jakarta has caused pollution. For example, the open dumping ground located at the blocked Ciliwung river is capable of absorbing waste for 10 years, but whenever there is the opportunity, waste is taken to the suburban areas such as Pasar Rebo and Pasar Minggu.

Waste supply at those agricultural areas were received enthusiastically by farmers. The waste is used as compost which increases their crop yields.

Waste disposal by sanitary landfill must be carried out by a sandwich system, covering the waste with soil or sand usually with at a ratio of 2:1.

An ideal site for waste disposal should be close to the waste producer and provide no harm to the environment. Sanitary landfill in Jakarta is difficult to conduct due to non-availability of suitable locations and the high cost calculated as follows:

Should the estimated waste volume be about 4,000 m^3/day, equivalent to 2,000 m^3 after compaction, the total soil or sand needed for layers will be 1,000 m^3 costing Rp. 500/m^3 or a total of Rp. 500,000/day (US$800). Therefore, the application of this disposal method will cost Rp. 180 million annually for sand alone.

Waste disposal by incineration, compaction or composting will cost twice as much as the above amount.

For leveling purpose, the department has several bulldozers at the disposal sites.

Moreover, the application of the sandwich system in Jakarta will require mud excavators as the ground water is not very deep.

Furthermore, and this is not less important as it supports the whole operation, the department has built a workshop for repairs to dump trucks as well as having plans for the procurement of lathes, service bridges and other equipment.

Truck repairs and maintenance is organised by grouping the mechanics and each group is responsible for a number of trucks. Other activities such as wiring, dynamo repair, welding and repairs to the engine and to other parts of the truck are conducted by the group.

Law Enforcement

The Jakarta authorities have used law enforcement as a factor to discipline the people whose behaviour has been deteriorating lately. As an example, the construction of a steel fence along pavements is in intended to prevent the people from squatting on such places. This action was first considered as an "iron hand", but gradually the sense of discipline is coming back and its meaning is being realised.

The Cleansing Department is also performing its "law enforcement" programme through its special police force.

In Jakarta, the Cleansing Department's sub-offices in the 5 areas have certain places proclaimed "clean areas" such as shopping centres, Pasar Baru Street, Kramat Raya, Blok M, Melawai Street etc.

The introduction of law enforcement in cleanliness has produced positive although not widespread effects.

CLEANLINESS PROMOTION

The proper maintenance of cleanliness in Jakarta to the prerequisites of a modern city is only possible if members of the community have a uniform understanding and attitude on the sanitation problem.

It is obvious that some of the city people are conscious and actively participate in solving the problem of cleanliness, but others show their irresponsibility particularly on the waste problem in the capital which is now quite critical.

Apathy and carelessness about environmental problems is due to traditional bad attitudes of the city people. Understanding and consciousness about the problem of cleanliness is very limited.

It seems that cleanliness belongs only to a small group of elite. While some communities consider that dirt caused by waste disposal will not directly disturb their environment, apathy towards proper waste disposal is traditional and difficult to overcome in a short time.

Up to now, many people still dispose of wastes into the river, sewerage or in the middle of a road and they regard such actions simply expedient and not an offence. Some people do not realise that inappropriate waste disposal will damage their environment.

In view of the complexity of the problem, it is necessary to take persuasive measures and convince the people of the importance of cleanliness and for them to adopt it as a natural attitude. It is necessary to promote consciousness and understanding that careless disposal of waste is prohibited and will ruin the environment. Through enforcement of cleanliness regulations people participation in maintaining a clean environment will be promoted.

People participation can be promoted in 4 ways:

1. Education through elementary schools to the pupils.

2. Two-way communication. To promote interest in this cleanliness movement, there should be understanding and consciousness on both sides between the authorities and the city people. The authorities are ready to step down and observe it on the spot and provide necessary information while the people should not have any hesitation in sending their problems to the authorities. For example, suggestion boxes will be made available at government agencies to receive any compaints or problems reported by the people who can ask for a solution.

3. The city's public facilities. The government must provide public facilities such as pavements, street lighting, public lavatories in certain place such as shopping centres, petrol stations and other public utilities.

4. Law enforcement. Everyone should obey the law and realise its benefits and the security it provides. Likewise, anyone who breaks the law should receive punishment accordingly.

CITY CLEANLINESS IN THE FUTURE

The prospect of city cleanliness in the future needs projections based on observation of the past problems.

The main problem being faced now is urbanisation with all its aspects which increases the production of waste.

Furthermore, a forecast should be related to progress of technology and the growth of industrial estates.

The following factors influence future plans:

Urbanisation, technological progress and industrial development, the plan to make Jakarta a metropolitan city, pollution solutions, waste treatment, infrastructure and facilities in maintaining a clean environment and co-ordination between departmental units. These factors are considered individually.

Urbanisation

Jakarta's population is growing from year to year as stated earlier and urbanisation is mainly responsible, leading to a high rate of unemployment among other things.

Jakarta has now introduced family planning and the city is now closed to potential migrants. Nevertheless, a high population growth accompanied by lack of city amenities and the low standard of living for the majority have caused a low social awareness and disrespect for law and order and other regulations. This is reflected by the fact that some people are still disposing their domestic waste in places not prepared for it. Certainly, this poses a great challenge to the Cleansing Department.

Technological Progress

At present, we are still at the first stage of industrialisation. Viewed from the experiences of developed countries, industrialisation has reflected living standards. Industrialisation is also the manifestation of technological progress as can be seen in Jakarta where the products of technological progress have been much used. This can be seen in the fields of communication and transportation.

Jakarta now suffers from 2 sources of pollution. The first cause is the social and economic condition of society, and the second one is the application of technology in certain fields such as air pollution from car exhausts.

Consequently, progress in technology should be able to prevent environment pollution as long as preventive measures can be undertaken through accurate planning by studying the experiences of industrialised, developed countries. In this connection, Jakarta authorities plan to establish an industrial estate with the purpose of providing job opportunities on one hand and to avoid industry's negative effects on the other.

Industrial waste from this estate will be the most important issue for the Cleansing Department. Such industries will produce wastes which are complex in nature in gaseous, liquid and solid forms. The consequencies of this requires the Cleansing Department to take appropriate measures.

Jakarta's Transformation into a Metropolitan City

As the capital city, Jakarta, like any other capital city, is transforming into a metropolitan city.

According to the master plan for Jakarta from 1965-1985, it is expected that Jakarta will fulfil the criteria of a metropolitan city.

The master plan calls for:

- Housing as a primary need of the population. This plan is implemented by considering the conditions for area development, population density, necessary facilities, security and cleanliness. As for the last issue, it reflects that the cleanliness of the environment must be easy to maintain. In this context, it is much better if a master plan on the cleanliness issue in Jakarta is included.

- Facilities and public services. The daily needs of the population must be satisfied with the purpose of promoting a healthy environment. Basically, require public services include:

- Portable water supply. For the present, the supply of 150-200 litres/man/day is an ideal figure for Jakarta. By supplying that need, it is estimated that about 70 per cent of the water will be thrown out as used or dirty water. It is appropriate, therefore, to plan channeling system for the dirty water. The most important thing here is that the dirty water does not pollute the environment. In such a situation, the application of a water disposal system where the water can be recycled or taken away to an open area without harming the environment is necessary.

- Electricity. In 1966, per capita consumption was 22 watts and it is planned to increase it by 1985 to 149 watts per capita. The most important aspect that has to be noted by the Cleansing Department is the location of the generators which should not disturb the environment with noise, smoke or any other wastes.

- Gas. Although gas is not a basic need, viewed from the aspects of security, cleanliness, flexibility and efficiency and in line with Jakarta's designation as a metropolitan city, it is estimated that average consumption will be 101 m^3/capita annually in 1985. Considering this increase, the location of the gas plant should avoid the present experience where the surface of the Ciliwung River is polluted.

- Public transportation. Public transport in Jakarta consists of:

    - A railway system with rapid transit
    - Buses and mini buses
    - Taxis
    - Small three wheeler cars.

It is estimated that 6,250 buses will be needed in 1985 with the understanding that ricksaws will be replaced by other small forms of transport. The consequence of the increasing number of cars is the higher degree of air pollution from exhaust fumes.

POLLUTION PROBLEM

Although pollution is not critical in Jakarta as a whole, the city does face a pollution problem in certain areas.

First, solid wasted dumped in great quantity in the wrong place can pollute the soil, water or the atmosphere and is specifically ralated to the people's health and social welfare. Further, rivers in Jakarta, which were clear before now appear dirty due to discarded waste and biological life in the water is diminishing or is non-existant. Moreover, flow of rivers has been disturbed.

Water pollution is considered the first priority to tackle in Jakarta.

Industrial smoke from chimneys as well as exhaust fumes from cars have caused air pollution.

In addition there is noise pollution caused by the sound of aircraft, cars and factory machinery, etc.

Controls should be implemented effectively against these noises in order to avoid changing the quality of the environment with its negative effects on health and community welfare.

Infrastructure, Facilities for Environmental Control

Physical cleanliness in Jakarta can be divided into 2 groups with different responsibilities, one group concerned with the problem of solid wastes, so far handled by the Cleansing Department; the second group dealing with the problem of air, ground water and sound pollution etc. Where such management has not yet been co-ordinated Jakarta's authorities must face up to this in the future.

The Cleansing Department will continue to tackle the problem of waste as a whole including collection, transportation and treatment. Co-operation practised so far with the community organisations will be intensified in line with percentage increase of population that can be served by the department.

If at present only about 20 per cent of Jakarta's population receive the service of the agency, it is expected that this figure will increase gradually and more waste will therefore be transported.

A pilot project to serve community in densely-populated areas will be implemented soon. The service will then not be limited to residential areas of rich people and other areas will receive the same service in accordance with the city's structure .

The city's structure and a collection network will expedite efficient transportation of waste. The plan will determine the number of trucks, distance covered, routes taken, possible speed and the final dumping sites. As far as possible, the present trucks will be used to the maximum and in the meantime the quality of the trucks will be improved.

Ideally the modernisation of infrastructure and facilities operated by the Cleansing Department will be according to the transformation of Jakarta into a metropolitan city. This problem cannot be separated from the financial situation, however.

It is a fact now that some city residents have made financial contributions towards the collection and transportation of waste but unfortunately this has not been not co-ordinated. It is expected therefore that Jakarta's authorities will arrange for a co-ordinated fee collection for dumping and transportation of waste.

According to the statistics, Jakarta's communities living in elite regions have no objection to "cleaning fees" as long as the area is totally clean. In fact, this should be considered as community participation.

In the middle class areas, co-operation among residents can be organised so that the collection and transportation of waste can be performed better.

The problem of air, water, ground water and noise pollution is not critical. This does not mean that consideration should not be given to it, indeed, in view of the experiences of developed countries, the problems of air, water and other pollution should be considered immediately, especially those caused by industrial growth in Jakarta.

Based on a decision of the Governor of Jakarta in 1973 the Cleansing Department formed a committee to work out programme for the implementation of a 1971 regulation dealing particularly with the standardisation of waste affecting the air, water or coastal areas.

Short-Term Plan

Due to a shortage of experts in the field of city cleanliness problems, the Cleansing Department plans to recruit staff in the fields of sanitation techniques, biology, chemistry, engineering, sociology, public health, hydrography and economics.

These experts are prepared to analyse the problems and aspects of city cleanliness in Jakarta and they are expected to continue working with the Cleansing Department.

Further, as the short-term plan progresses, the Cleansing Department will implement a long-term plan with a service organisation structure with the experts expected to be capable of handling the problems they have analysed during the short-term plan. They are expected to be the core staff of the Cleansing Department.

Waste Treatment

Waste is disposed of by several recognised methods such as burning out, incineration, open dumping and used by farmers as compost, etc.

The best method is both economical and practical without harming public health. The present system used is by dumping or landfill.

Sometimes, this is accompanied by burning in order to decrease volume.

Waste disposal by incineration and other methods is also generally practised but the quality of waste processed through these methods is very limited. On the other hand, such methods are not satisfactory because about 30 per cent of the volume is in the form of dust, hard matter or metal and other materials.

In the long-term plan, the possibility of incineration must be considered but there are both advantages and disadvantages.

Benefits include the fact that the treatment area is relatively small; there is the possibility of centralised placement; the burnt remains such as dust are free from organic matter; various kinds of waste can be treated by this method; it is subject to climate changes; operation time is flexible — 8, 16 or 24 hours a day; and it provides a source of heat that can be utilised.

Disadvantages are high initial costs — about US$ 3,500 - $ 5,000 per tonne for 24 hours for complete construction;

The operational cost is high and requires personnel for operation and maintenance. High temperatures, dust and the variety of materials treated will affect the burners, engines and the working place. Therefore, much time is required for repairs. The cost of this is estimated at $ 3 - $ 7.50 per tonne. There can be local pollution from untreated waste (if the capacity of the incinerator is small) while air pollution from an incinerator with a big capacity can pose at problem.

From the public health point of view, the dumping system is unsuitable as it encourages the multiplication of rats, mosquitoes and flies and also there is also the possibility of polluting the ground water. If these wastes are burnt, smell and smoke can be a nuisance to the community. It is not exaggerating to say that the open dumping system has no place in modern waste treatment.

Composting, is one method which has received significant attention but is not acceptable in some places in Jakarta. This method requires bearing in mind the high cost and difficulty in marketing. For this reason, many countries have discarded this method in recent years.

Conventional composting performed by farmers is still continued because it benefits the farmers as well as lessening the waste volume that must be disposed.

The best waste disposal method, as mentioned above, is sanitary landfill. However, a shortage of land makes this difficult to implement.

This method is implemented as follows:

- The waste are levelled down or placed on the already prepared site and spread out, levelled and composted in that layer.

Later, compaction is introduced.

- The waste is covered by non-porous soil taken and the heap is periodically compacted.

When the area prepared has already been filled in, it can be used as a place for light activities or contruction such as a golf course, tennis court or a flower garden as a city lung, etc. Generally, sanitary landfill can be implemented in 2 ways: area fill or trench fill.

Area fill is implemented in an open place, flat or hollow, while trench fill uses prepared ditches. The choice of method can be according to site conditions.

Considerations in the implementation of the above methods are the selection of technical and economical locations and community acceptance. No less important is the size of the land desired and the prevention of the contamination of ground water. The size of the site depends on several factors such as waste volume, conditions, equipment needed and financial considerations.

Nevertheless, a study indicates that sanitary landfill is the cheapest method compared with composting and incineration.

This can be seen from Table 6.

<u>Co-ordination of the Service Units</u>

As explained earlier, Jakarta has experienced pollution in limited areas. Faced with growing industrialisation, however, the handling of environmental pollution requires attention to see that whatever has happened in developed countries does not necessarily repeat itself in Jakarta. The cleaning service in this case has studied the plan on

Table 6. Relative Cost of Different Waste Disposal Techniques in US

Method	Land Acreage	First cost $/year	Operation cost $/year	Disposal cost/year
Composting	5	2.91	4.01	6.92
Incinerator	3	2.09	2.90	4.98
Sanitary landfill	40	6.78	0.90	1.68

This table is from Maricopa County (United States of America). Existing capacity is 300 tonnes per day.

handling and managing the problem as specified in the short-term and long-term programmes.

On the other hand, from the experience in some cases in the field of industry, it is clear that control on environmental pollution, covered by Region Regulation No. 12, 1971, is still not effective.

It cannot be denied that the Office of Industries has the primary role with industrial problems, particularly with regard to production quantity and quality, type of industry, etc. but it is a fact that industrial wastes cause pollution and this involves other concerned agencies. For example, one industry, having received a licence to operate, cast out gas into the air and polluted the environment.

If an industry discharges waste into water which is a source of drinking water or used for fisheries or agriculture, then, the responsible of agencies are the City Service for Drinking Water, the Office of Fisheries Service or the Agriculture Service.

In view of the above situation, it is felt necessary to have a co-ordinated and synchronised programme covering various service agencies of Jakarta authorities having involvement in the aspects of environmental pollution.

For implementation, it is expected that the co-ordinated and synchronised activity will reflect the content of the Regional Regulation No. 12, 1971 and No. 3, 1972 by introducting preventive measures without neglecting other social and economical aspects.

During the transitional period it is necessary to start preparing to identify infrastructures and facilities needed by a staff of experts as shown in the short-term plan of the Cleaning Service and when the time has come this staff will manage the problem of pollution in Jakarta. This will be the beginning of the long-term plan execution as explained earlier.

In addition, as guidance special standards or criteria for permissible waste which that can be tolerated by Jakarta will be drawn up.

Nevertheless, the preparation of these criteria should be conducted after making a thorough study and survey, monitoring areas expected to experience pollution.

As outlined before, the problem of pollution is not only limited to the region but also is a national and international concern and consequently a functional agency should be established between the central and authorities.

Several countries facing a serious environment pollution problem have established a special agency according to their needs and problems. Likewise, it is feasible for the Urban and Environmental Research Centre (PPMPL), initiated by Jakarta authorities, be extended in its functional relation with the central Government.

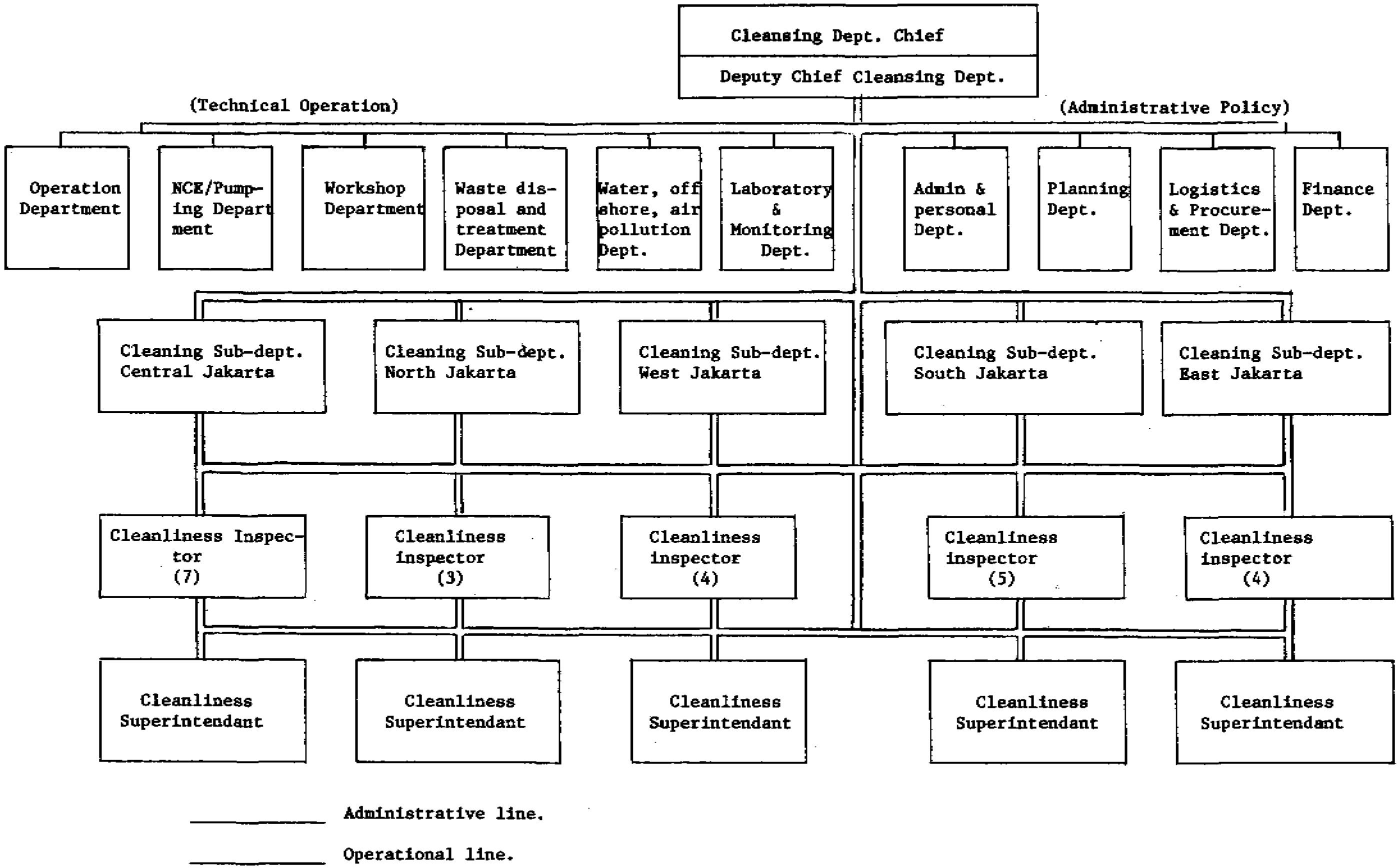

Fig. 1. Organisational Structure of Jakarta Cleansing Department

SOLID WASTE DISPOSAL IN KOREA

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INTRODUCTION

The Korean peninsula is a temperate zone and is located between northern China and Japan. The total population of South Korea was 36,436,000 in 1977. Sixty per cent live in urban areas where there are 36 major cities and 147 townships. Of the 36 major cities, Seoul is the political and commercial centre of the country and has a population of 7,308,000, not including transients. Most industries are located around the coastal zones of the peninsula where products ranging from heavy-sized ships, oil refinery derivatives and electronics to soft drinks are produced. Exports in 1977 amounted to US $ 10,000,000,000. The GNP was US $ 860 as of 1977.

Solid Waste Production

As Korea is in a temperate zone, the amount of waste varies greatly according to the different seasons, the peak month being around November. However, the waste production per capita per day is 0.74 kg to 1.96 kg and an average is 1 kg.

CHARACTERISTICS OF WASTE

According to a survey of domestic waste from 28 major cities, out of the total wastes, about 8 per cent (Seoul 14 per cent) is combustible and the rest was found to consist of noncombustible materials. The composition of municipal waste by weight was found to be: 78 per cent ashes; 4 per cent mixed paper; 1.8 per cent PVC products; 0.9 per cent glass; 0.6 per cent ceramics; 0.6 per cent wood; 0.4 per cent metal; and 13.7 per cent other materials.

The heat value is about 300 kcal/kg and water content is about 30 per cent. The BOD of the leachate is around 18,000 mg/l.

Since a large portion of the waste is classified as noncombustible, it is impractical to incinerate without sorting beforehand. Most of the

Table 1. Solid Waste Production in Cities

Areas	Population	Waste (t/year)	Kg/cd
Seoul	7,308,000	4,114,175	1.5
Busan	1,830,000	494,283	0.74
Daegu	1,108,000	569,735	1.41
Incheon	582,000	201,947	0.95
Gwangju	465,000	144,000	0.86
Daejeon	382,000	133,430	1.00
Masan	271,000	49,083	0.49
Jeonju	238,000	83,585	0.96
Cheongju	121,000	29,200	0.66
Woolsan	139,000	40,980	0.81

Table 2. Solid Waste Production in Small Townships

Areas	Population	Waste Generated (t/year)	Kg/cd
Yeonju	42,000	15,340	1.0
Seokipho	24,000	10,800	1.25
Dogae	12,000	2,920	0.67
Wando	11,000	2,160	0.54
Yeoju	20,000	14,400	2.00

combustible material originates from hard coal which is used as a domestic fuel and hard coal ashes comprise about 65 per cent of the total noncombustible materials. However, the amount increases during the winter.

METHOD OF DISPOSAL

About 99 per cent of all solid wastes generated in the country are disposed of by sanitary landfill or by open dumping on lower land for land reclamation. For Seoul, there are 4 landfill sites which are located 26-35 Km from the outskirts of the city and which will dispose of 11,271 tonnes a day (specific gravity of the waste is $0.47t/m^3$). Although some studies have been conducted on waste composting, this method is not yet being used.

In Seoul, noncombustible materials which consist mainly of ashes from hard coal are recycled to make concrete blocks. Approximately 360 tonnes of such blocks are produced each day.

ADMINISTRATION AND LEGISLATION

The Government is responsible for the disposal of domestic waste with the Ministry of Health and Social Affairs arranging for the planning, supervision and evaluation of the waste management. At the local level, the provincial government, city government or town council is directly or indirectly responsible for the field programmes.

The Waste Disposal Law is used in combination with the Environmental Preservation Law and the Ocean Pollution Control Law to directly and indirectly regulate waste disposal in general.

SOLID WASTE MANAGEMENT IN METROPOLITAN MANILA, PHILIPPINES

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INTRODUCTION

Land and/or soil, water and sometimes air pollution is caused by uncollected and improperly disposed solid waste matters. These conditions have been experienced by Metropolitan Manila residents.

The resulting ill-effects are generally detrimental to the health of the citizens; an eyesore; and the slow death of the areas within the dumping sites.

Essentially, through proper solid waste management, land/soil pollution can be minimised if not eradicated. Solid waste management is the systematic management of refuse storage, collection and disposal. The term solid waste refers to garbage, trash, rubbish, litter, junk or refuse from any source, particularly from residences, commercial establishments, factories and agricultural areas.

The overall approach adopted in this paper is as follows:

The existing situation is presented, indicating refuse quantity and quality, methods used in storing, collecting and disposing of solid waste by major sector and the government undertakings regarding those aspects; the problems are identified; an analysis of the problems is made, indicating the causes and implications of the problems; and the conclusions/recommendations to minimise if not eradicate the problems in solid waste management are state and expounded.

THE PRESENT SITUATION

Refuse Quantity

Generally, the quantities of refuse vary widely from city to city, and, within a city itself, they also vary from season to season, from day to day and from zone to zone. The quantities of municipal refuse produced in the Metro Manila area are expected to increase at a high rate due mainly to 2 factors: population growth and per capita increase in refuse production (See Table 1).

Table 1. Present Refuse Quantity in Metro Manila

Areas	Estimated Population	Computed M^3 Day	Amt. of Refuse Collected M^3 Day	% Refuse Collected
Manila	2,459,409	2,300	2,000	87.34
Quezon City	1,450,155	2,000	1,884	94.20
Caloocan	499,428	657	480	73.05
Pasay	316,348	410	205	50.00
Navotas	101,772	164	99	60.40
Malabon	183,647	297	200	67.30
San Juan	157,845	213	156	73.20
Mandaluyong	217,085	330	250	75.80
Makati	447,678	640	520	90.60
Pasig	274,091	320	198	62.00
Valenzuela	196,289	260	162	62.30
Marikina	206,583	272	216	80.00
Pateros	34,403	35	10	19.00
Taguig	77,332	130	18	14.00
Parañaque	209,733	265	198	75.00
Las Piñas	100,291	122	80	66.60
Muntinglupa	110,291	175	52	30.00

Note: Data as of April, 1977
Source: RESC - MMC

Refuse Characteristics

An analysis of refuse in Metro Manila conducted by Pacific Consultants International showed that moisture contents of samples were 53 per cent to 58.5 per cent for residential areas, 63 to 70 per cent for market areas and 51 to 53 per cent for commercial areas with street sweeping. These moisture contents appear to be relatively high compared with the average moisture of 28 per cent and maximum of about 40 per cent in the United States.

The significance of such a high moisture content suggests that the refuse is not suitable for incineration without the addition of auxiliary fuel or pre-treatment by sorting or screening to remove most of the combustible content. This was probably one of the many difficulties encountered by the Quezon City Government when it operated its incinerator. The refuse density was found to be about 0.3 tonnes/m^3 for the Metro Manila Area.

Storage

These solid waste matters are stored using various methods. The most popular is the use of cans. The sizes of the containers are not uniform despite the ordinances promulgated. The containers generally used are too small to contain all the refuse produced by a household.

An average Filipino family of 6 would produce approximately 5 kg. If this was composed of litter and rubbish, the volume would be more than that which can be contained in one kerosene can. This is the typical container used by a household.

Separation of the different types of solid waste prior to storage is not practised among the households and commercial establishments in Metro Manila. Scavengers therefore find it useful to get saleable materials from the refuse receptacles prior to their final disposal. Sometimes the better receptacles are lost in the process.

In advanced countries, grinders are used to reduce the volume of refuse prior to storage or ground refuse is disposed of through sewers. None of the major hotels and markets in Metro Manila use this method of garbage storage-disposal.

Collection

Kerbside service, alley service and set-out/set-back services are provided in Metro Manila.

Kerb service is the most popular type of collection service provided by the cities and municipalities to the residential, business and agricultural areas. By special request, set-out service is provided.

Solid waste collection in Metropolitan Manila is performed both by local government and by private contractors. Some municipalities and cities make use of contractual services to augment their inadequate collection equipment. All of the localities in Metro Manila need additional equipment in order to improve the efficiency of the service they render. This means an increase in the number and capacity of dump trucks used for refuse collection; the provision of compaction equipment within each truck and the provision of special refuse collection equipment like fork-lift and towing apparatus.

However, a major development of collecting solid waste matters has been effected by the creation and of the Refuse and Environmental Sanitation Centre of the Metro Manila Commission. A more detailed discussion on this is made later.

Disposal

The volume reduction and disposal methods normally used in Metro Manila are sanitary landfill, composting, open dumping and open burning.

Solid waste in Metro Manila is dumped in several places. In spite of ordinances prohibiting it, vacant lots within the city proper are being used as dumping grounds for refuse. Esteros and other open bodies of water are not spared from this. Thus the Pasig River became a heavily polluted river in the last 10 years until measures to control the problem were implemented.

There are no readily available records to enable measurement of the efficiency of operation and cost of maintaining a dump site. Apparently, this is already included in the evaluation of the efficiency and cost of collecting a tonne or cubic metre of solid waste.

Among households with large gardens or yards, the open pit system is a popular method of disposing of solid waste. Ordinances passed by the local government units in Metro Manila prohibit this practice without prior permission from the Municipal Health Officer. The burning of refuse and litter in open pits contributes to air pollution. Also because most of the area in Metro Manila is below sea level, the burial of refuse contributes to ground and water pollution.

Disposal of solid waste would not be a problem if the ordinances regulating it were properly enforced by government agencies and followed by the citizens. Separation of wet and dry solid wastes would also help in solving the problem. Wet refuse may be sold as feed to piggeries or poultry farms. And the litter, rubbish, junk and refuse may be sold for profit. Those that cannot either be fed to animals or sold as junk may be stored properly for collection.

THE REFUSE AND ENVIRONMENTAL SANITATION CENTRE

The study of the Refuse Management System (REMAS) of the land/soil pollution control was made a pilot study by the Department of Public Works, Transportation and Communications and began on July 1, 1975.

The findings relating to environmental sanitation were extracted and combined with the approved Refuse Management System to form a programme of a wider-ranging Environmental Sanitation and Protection System Study.

This new grouping of activities meant an integration of the refuse and environmental sanitation activities in the local and sectoral levels of Metro Manila thus the new name of the control office is REFUSE AND ENVIRONMENTAL SANITATION CENTRE (RESC).

Factors considered in this study are the cost (operation, maintenance and capital), environmental factors, resource conservation (energy, materials and pad) and institution of factors (political feasibility, as well as legislative constraints and administrative simplicity).

A master plan for refuse collection and disposal for Manila and suburbs was formulated. The methods, procedures, advantages and financing methods were enumerated in the said master plan.

INDUSTRIAL WASTE ESTIMATE

Industrial solid wastes are collected and disposed of by the industries themselves or by the use of the refuse disposal service of the Refuse Environmental Sanitation Centre. Accordingly, a substantial amount of industrial solid waste is mixed with domestic solid waste. Larger factories have their own refuse trucks and haul refuse to the dumping site where they are charged a dumping fee.

Table 2. Waste Disposal by Sector in Manila and Suburbs

AREA	No. of Dumptrucks		Dump Site		
	Gov't	Private	No.	Location	Area (ha)
Quezon City	19	47	2	Tiangco Prop. (near La Mesa Dam)	18
Caloocan	11	-	1	Dolor Prop. (Constitutional Hill)	10
Malabon	-	11	1	Julian Felip St.	2
Navotas	-	12	1	Gov. Pascual Ave.	2
Valenzuela	9	-	-	Canumay	-
San Juan	3	10	-	Quezon City Manila Gravel Pit Land near boundary of Q.C. Montalban	-
Makati	-	-	-	-	-

Table 2. (Continued)

AREA	No. of Dumptrucks		Dump Site		
	Gov't	Private	No.	Location	Area (ha)
Pasay	-	7	2	-	-
Mandaluyong	-	13	-	-	-
Paranaque	3	-	-	-	-
Las Piñas	3	2	1	Pulong Lupa Las Piñas	25
Muntinglupa	-	-	-	-	-
Pasig	6	-	1	Taytay, Rizal	-
Marikina	-	12	1	Concepcio, Marikina	
Taguig	-	-	-	-	-
Pateros	-	-	-	-	-
Manila	85	-	1	Rodriquez, Balut, Tondo	30

Source: MMC (April, 1977)

Table 3. Number of Factories in Metro Manila (1974)

AREA	NO. OF INDUSTRIES	TYPE OF INDUSTRY
Manila	983	Lumber yards, saw mills, garment, printing press, motor works, machine, furniture shop, etc.
Quezon	4,161	Manufacturing, repackers, tanneries
Makati	396	No data
Pasig	189	No data
Malabon	167	Various types
Marikina	20	Various types
San Juan	380	Shoe manufacturers
Navotas	201	Various types
Valenzuela	407	Textile, socks, plastic, etc.

Source: Pacific Consultants International, in association with Basic Technology and Management Corporation (1974), Master Plan for Refuse Collection and Disposal for Manila and Suburbs.

Table 4. Type of Industrial Waste in Metro Manila Area (1974)

Type of Industry	Industrial Waste	Method of Disposal
Guns and Bullets	Small pieces of bronze, cartons, papers	Private contractor
Cigarettes	Cigar waste and reject bobbins	Private trucks
Tyres	Pieces of rubber	Burning
Plastic	Small pieces of plastic cartons	Burning and thrown into pit
Aluminum and cartons	Pieces of aluminum cartons	Private contractor
Textile and Printing	Wrapping papers plastic and cartons	Burning
Candies and other allied products	Cartons, cans peelings of fruits	Private contractor
Foodstuff	Cartons	Burning

Source: Pacific Consultants International, in association with Basic Technology and Management Corporation (1974), Master Plan for Refuse Collection and Disposal for Manila and Suburbs.

Table 5. Amount of Refuse per Dump Site per Day

AREA	DUMP SITE	AREA (ha)	REFUSE (M^3/day)
Quezon City	Tiongco Prop. (Manila Gravel Pit) Road, near boundary of Q.C. and Montalban	18	1,884
Caloocan City	Dolor Property (Constitutional Hill)	10	480
Malabon	Julian Felipe St.	2	200
Navotas	Gov. Pascual Ave.	2	99
Valenzuela	Canumay Valenzuela Tiongco Property	-	162
San Juon	Manila Gravel Pit Road (near boundary of A.C. and Montalban)	-	156
Makati	Tiangco Property (Same as Q.C.)	-	520
Pasay	Tiangco Property (Same as Q.C.)	-	205
Mandaluyong	Tiangco Property (Same as Q.C.)	-	250
Parañaque	Pulong Lupa, Las Piñas	25	1,980
Las Piñas	Pulong Lupa, Las Piñas	-	80
Muntinglupa	Taytay, Rizal	-	52
Pasig	Taytay, Rizal	-	198
Marikina	Concepcion, Marikina	4	216
Taguig	Concepcion, Marikina	-	18
Pateros	Concepcion, Marikina	-	10
Manila	Rodriquez, Balut, Tondo	30	2,000

Source: Pacific Consultants International, in association with Basic Technology and Management Corporation (1974) Master Plan for Refuse Collection and Disposal for Manila and Suburbs.

SOLID WASTE MANAGEMENT PROBLEMS

Table 6 was designed to illustrate the solid waste management problems by sector (private and government), using the following as areas of references: storage, collection and disposal aspects.

The major and minor problems presented in the said matrix were clearly stated and the analysis of each and every problem shall be discussed.

Analysis of the Problems

Solid waste management problems can be viewed from 2 points, that of the private sector and that from the government. From the viewpoint of the private sector the basic problems encountered in storage are the loss of receptacles from home owners and the ordinance requirement of separating the different types of solid waste matters to dry and wet.

Receptacles, especially plastic containers and kerosene cans, are lost because they have other uses and can be sold for possible recycling. The separation of the different types of solid waste matters into dry and wet as required by some municipalities and cities in Metro Manila is considered by many individuals as waste of time and an irritation.

With regards to the collection of solid waste, some home owners and industrial plants complain about the frequency of collection and the efficiency of collection. Solid waste is collected from households, commercial establishments and industries at varying frequencies: daily, every other day or weekly. However, it has been experienced by most residents that solid waste collection at households is often infrequent.

Sometimes, collections are at such long intervals that they have to dispose these wastes in their gardens or in vacant lots. Moreover, refuse collectors are careless in transferring the contents of the receptacles into the dump trucks, thereby doubling the handling of the waste matters and scattering the left-overs.

In the disposal of solid waste many home owners have the practice of dumping their refuse and the like in their gardens or prepare an open pit for them to burn the refuse. This practice is tolerable provided a permit was previously secured. But home owners find securing a permit an additional burden on their part. Nevertheless, it should be noted that securing a permit is a precautionary measure to avoid fire within the neighbourhood.

A more serious practice is the dumping of solid waste on vacant lots. Aside from the mound of waste, there are nasty odours caused by dumped intestinal parts of fishes, chickens and the like. This becomes the source of mosquitoes and flies in the neighbourhood.

Table 6. Solid Waste Management Problems

AREA OF CONCERN \ SECTOR	PRIVATE	GOVERNMENT
STORAGE	* Lost of receptacles *The requirement of segregating the different types of solid waste matters to dry and wet.	*Non-compliance of many citizens in the implementation of sanitary ordinances. *Varying sizes of receptacles and sometimes without one, thereby the waste will still be collected one after the other.
COLLECTION	*Insufficiency of collection service - frequency of collection - inefficiency of collection	*Increasing volume of the waste to be collected brought about by urbanization and industrialization of Metro Manila. *Increasing financial requirement to cope with the increase in the demand of personnel, facilities (i.e. equipment) and the high cost of maintaining available but dilapidated equipments brought about by the increase of volume of waste being collected.
DISPOSAL	*The practice of backyard open dump without the necessary permit.	*Open dumping is being resorted to, a method universally condemned by public health authority. *Open dumps are easily filled up because no method of compaction or volume reduction is done before the waste matters are dumped. *Location of dumpsites. *Eyesore in dumping sites *Disposal in estero and the like, and vacant lots *Cost of maintaining a dump site. *The use of other methods (i.e. incineration and compost plant) of disposing waste.

From the Government's viewpoint, the basic storage problems encountered are the non-compliance of most citizens in the implementation of ordinances and the varying sizes of receptacles, sometimes being without any at all, thereby allowing waste to accumulate. Some people have the habit of not complying with the implementation of sanitary ordinances (i.e. backyard dumping without a permit) and it would take time and much effort to change this.

Varying sizes of receptacles is inevitable but many containers are dilapidated type and should just as well be disposed of.

Some people simply place their waste matters in the streets without any receptacle. This creates additional problems of collection and delays the operation. There is double handling of waste and lots of time is wasted over this.

One of the major problems being encountered in solid waste management is the increasing volume of waste being collected due mainly to urbanisation and the industrialisation of Metro Manila.

With the increasing volume of waste to be collected, another major problem arises and that is inadequate funds. The administrative machinery, the need for new equipment and the maintenance of existing equipment tends to increase as the volume of waste increases.

The general fund of the local government unit is the major source of funds for the operating expenses of the offices, including that of solid waste management. There are instances when funds for the year are insufficient and have obviously affected the expenditures in solid waste collection and disposal, thereby resulting in an inefficient performance brought about by the inability to purchase spare parts for dilapidated equipment. Moreover, there are times when there is a need to hire additional garbage collectors and to buy of new equipment and funds for these purposes ought to be requisitioned.

With regards to the disposal of solid wastes, the problems encountered by the Government are the open dumping method used; locations of proposed dump sites; eyesores at such sites; disposal in esteros and the like, and vacant lots; the early filling up of open dump because no method of compaction or volume reduction is done before the waste matters are dumped; the cost of maintaining a dump site and the use of other methods of disposing waste.

Open dumping has unhealthy consequences which is why public health authorities condemn this method. On the other hand, this is the simplest and quickest method of disposing of waste compared to incineration and composting. However, this method has great long-range implications as far as unhealthy consequences is concerned.

In open dumping there is no method of compaction or volume reduction before waste is dumped. Waste is just left mounting as time goes by. This is an eyesore although dump sites are normally located far away from urban centres.

With the rapid expansion of urban land use (i.e. subdivisions) in all the cities and municipalities of Metro Manila, it is evident that subdivisions developed and being developed are reaching the environs of dump sites. The consequent problems are the transfer of the dump sites and the manner of compacting or reducing the volume of waste in the dump site.

The location of proposed dump sites or the transfer of such is another problem. However, based on the Development Plan of Metro Manila, those dump sites which were against the principle of human settlement were pinpointed. Moreover, studies are on going as to the additional use of incineration and compost plants.

People residing along estero and other bodies of water including Manila Bay and the Pasig River illegally dump their solid wastes in these of water causing pollution.

The same is true to industries located on these perimeters. However, safeguards to check this practice have not been ignored by the government and measures have been formulated and implemented.

The creation of the Refuse and Environmental Sanitation Centre was a way to come out with an area-wide approach to understand solid waste management. Solid waste management is an integral part of the total Environmental Sanitation and Protection System which is under the overall jurisdiction of the centre.

There are a handful of advantages in this regard:

1. Closer co-operation among contiguous local government units promotes uniform enforcement of rules and regulations on solid waste storage, collection and disposal;

2. Because of the number of local government units affected and the size of the population demanding the service, it will be easier to obtain assistance, particularly financial assistance, from the Metro Manila Commission or the national Government;

3. There will be greater flexibility in locating disposal sites; and

4. It will be easier to obtain the support of the media in educational campaigns.

A master plan for refuse collection and disposal for Manila and Suburbs was drafted. Some constructive comments are as follows.

1. The recommended centralised dumping site is not well-defined. The exact location and approximate area needed, including the estimate for the construction of an access road must be stated.

2. The proposed Pilot Project in La Loma, Quezon City should include composting.

3. During the period of implementation which will take time due to the installation of the facilities, no alternative proposal was recommended to partially remedy the refuse problem while the construction of the facilities is under way.

4. The sites recommended for the construction of transfer stations may not be available.

5. The storage and handling of compost, and maintenance should be dealt in more detail.

The point raised here is that the master plan could still be improved on. Comments such as the ones mentioned above only denote ideas to improve the whole system in general.

CONCLUSION

All of the localities in Metro Manila realise the importance of educating the people on proper storage, collection and disposal of solid waste. Yet not one of them has a regular appropriation for educational campaigns.

Civic organisations and concerned individuals should initiate a long range campaign of educating the citizens regarding the proper storing and disposal of solid waste matter, alongside with the government undertakings. An informative drive on the ordinances on refuse collection and disposal would make enforcement of rules and regulations easier for the administrative agencies. Also, the Government should be more strict in the inplementation of the ordinances.

Disposal of solid waste would not be a problem if the ordinances regulating it were properly enforced by government agencies and discipline were developed among the citizens.

There is a need for barangay members to co-operate closely to minimise the loss of refuse receptacles.

Proper storage of solid waste leads to the efficiency of the collection service. Local government units in Metro Manila require the co-operation of the home owners to take out and bring in their refuse receptacles at specified hours.

Present ordinances specify the use of proper size and capacity of refuse receptacles. They should not be overflowing with refuse. Extra large garbage receptacles may result to backaches among garbage collectors or there will still be the need of more than one person to lift it. However, the practice of storing garbage in large containers will not necessitate daily garbage collection; at most only twice or 3 times a week. Garbage left-overs necessitate gathering before collection thereby wasting time.

The use of proper collection facilities is another aspect of the solid waste storage problem. Most dump trucks used for garbage collection are open trucks. Dump trucks should be covered to avoid refuse from spilling to the ground and from polluting the air at places where they are parked. RESC is now using covered trucks but these are insufficient.

The RESC consultants recommended that the time of collection follow present practices for the time being in most municipalities, except a rapid change should be made to once every 2 days collection instead of daily collections. This was based on the reason that the cost of daily collection presses the municipalities and the citizens financially. In order to eliminate confusion by sudden changes, there is the need for close co-operation with the public, especially those who are not so familiar with the advantages of alternate two day collections and the need of households to use standard containers which have not been a too familiar sight in Metro Manila.

The local government units must provide for the use of a more sanitary method of refuse disposal which can be used for several years. This may be through the use of a sanitary landfill system, an incinerator or compost plant.

Sanitary landfill is the most appropriate system of solid waste disposal to be used in Metro Manila because it is the most economical.

The strengthening of the Refuse and Environmental Sanitation Centre through the provision of adequate financial support in undertaking the function of solid waste management is needed.

This office will provide and operate final disposal facilities, operate auxiliary bulk transfer facilities and a central motor pool. It will be responsible to help end one of the causes of inefficiency in refuse collection and disposal service which is the lack of adequate facilities for collection and disposal and the high cost of maintaining available but dilapidated equipment.

THE MECHANISATION OF STREET CLEANSING IN SINGAPORE

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INTRODUCTION

The concept of mechanisation of street cleansing in Singapore was first conceived in 1972 at a time when the newly-formed Ministry of the Environment was faced with the rising problem of labour shortage and recruitment resulting from the rapid rise in standards of living and where manual and menial tasks are generally shunned by the populace.

Mechanisation of street cleansing in the republic is expanding fast due to the rapid pace of urbanisation and industrialisation resulting in the phenomenal growth of roads and highways which require daily maintenance. The growth in fleet strength of mechanical sweepers from a mere 4 vehicles in 1972 to 44 vehicles in 1977 is a good testimony of this. In line with the Government's policy towards increased mechanisation and higher work productivity, the introduction of mechanical sweepers for street cleansing could not have come at a more opportune time. Moreover, it has been shown that mechanisation of street cleansing is a viable proposition in aspects of economics and effectiveness.

The introduction of mechanisation of street cleansing has raised the standards and status of street cleansing services in Singapore which is one of the few countries in the world with daily street cleaning and refuse removal. Presently, all major roads and highways are mechanically swept and with the constant emphasis on higher work productivity and maximum vehicle utilisation, roads within residential housing estates have been included in the mechanisation programme.

The mushrooming of self-sufficient satellite towns and the constant improvements to the environment in the city conurbations, with the provision of attendant amenities such as footways, pedestrian shopping precincts, open rest spaces and car parks has generated areas suitable for mechanisation especially with the highly-sophisticated and versatile machines now available on the market. However, mechanisation of fields other than street cleansing are planned for the future.

In anticipation of future needs, the ministry has announced plans to acquire more versatile mechanical sweepers to complement the existing fleet to help cope with the rapid development of roads and highways in the republic.

ORGANISATION AND OPERATION OF THE MECHANICAL SWEEPER UNIT (MSU)

The Mechanical Sweeper Unit (MSU) which was formed in late 1972 has undergone tremendous change in administration, management and operation since its inauguration. Although Singapore is administratively divided into 7 Environmental Health Districts, the MSU operates only from 2 of the districts, namely the Western and Eastern Urban Districts which are wholly responsible for all aspects of mechanisation of street cleansing in the western and eastern half of the republic respectively. The rationale for this set-up was the need to enhance operational efficiency and to facilitate the management and control of manpower and logistics to achieve higher work productivity and efficiency.

The 2 mechanical sweeper units come under the purview of the respective heads of the districts, the assistant commissioners of public health who are also responsible for allied public health services such as daily refuse collection, control of public health nuisances and all other aspects of environmental health work in their districts. They, in turn, are responsible to the Commissioner of Public Health at the ministry headquarters.

The mechanical sweeper units stationed in the 2 urban districts operate on similar lines and in close co-operation with each other with the basic objective of keeping the republic clean at all times. The unit functions throughout the year and currently operates on a 2 shift basis with the morning and afternoon shifts commencing work at 5.45 a.m. and 12.00 noon respectively.

Daily deployment of mechanical sweeper drivers are carried out by transport officers who are public health auxiliaries. All permanent drivers are invariably given fixed vehicles and routes to encourage them to take meticulous care of their vehicles and routes. The making of gutter brushes and other miscellaneous tasks are carried out by substitute drivers when they are on standby.

Before proceeding to work, all vehicles are thoroughly checked by the drivers and this takes about 10 - 15 minutes. To ensure that drivers do not indulge in malpractices during working hours, random inspections are carried out daily. All mechanical sweeper routes are so planned that under normal circumstances, drivers will be able to complete the route within the shift and this is confirmed by having trial sweepings with officers following prior to implementation. Dumping of silt is normally carried out in specified sites in the two government dumping grounds, except for the Wayne sweepers which discharge their silt directly into open tippers in the depot.

All sweepers are washed after every shift using high pressure water jets, detergents and brushes by the respective drivers who are paid a washing allowance. Cleaning of air filters by pressure air jets is also carried out by them. In addition to faults reported by drivers, physical checks are still carried out as not all damage or faults to the vehicles are reported. Minor mechanical faults are attended to in the depots by the technical staff to get the vehicles ready for the next shift. Operational problems encountered and reported by drivers, such as obstruction by overhanging tree branches and unauthorised parking of vehicles, are referred to the appropriate authorities for necessary action.

The 2 mechanical sweeper units have a combined fleet strength of 44 mechanical sweepers and caters for a total of 48 routes with a shift factor of 1.59 and covering a daily sweeping mileage of 2,152 km (1,345 miles). The mean sweeping mileage per route is 44.9 km. A sample of the mechanical sweeper route plans are shown in Figs. 1 and 2

Details on the distribution of the number and type of mechanical sweepers, routes, total sweeping mileage and shift factor of the 2 sweeper units in Eastern and Western Urban Districts as of June 1, 1978 are shown in Table 1.

TYPES OF MECHANICAL SWEEPERS EMPLOYED

The 4 different types of mechanical sweepers presently employed for street cleansing in Singapore fall basically into 2 main groups:

- Suction sweeper collectors which employ suction as a means of lifting silt and debris from surface swept to the hopper;
- Mechanical sweeper collectors where dirt and debris are carried from the sweeping brushes to the hopper by means of a conveyor mechanism.

The earliest type of street cleansing vehicle employed in the republic is the "Wayne" which comes under the second category. This type of machine has been gradually superseded by three other types of suction sweepers — the "Johnston", "Eagle" and "Yorkshire". The increasing popularity of this design is evident by the prevalent utilisation of suction sweepers in most countries with mechanical street cleansing.

As the majority of roads and highways in Singapore are mechanically swept, all the 4 types of mechanical sweepers in use are therefore robust and bulky machines. However, faced with the problem of increased traffic density in the city areas and the new satellite towns and the need to mechanise street cleansing of smaller roads in residential housing estates, there are plans to purchase sweepers which incorporate essential features of compactness and manoeuvrability.

Table 1. Mechanical Sweeper Distribution and Deployment

District	No. of Routes			Shift Factor	Total kerb length swept per day	Average length swept per route (km)	Type of Mechanical Sweepers				
	AM	PM	TOTAL				Eagle	John-ston	York-shire	Wayne	Total
W U D	16	10	26	1.62	1141.0 km (713 miles)	43.9	9	10	–	5	24
E U D	14	8	22	1.57	1011.0 km (632 miles)	45.9	9	9	2	–	20
Total	30	18	48	1.59	2151 km (1345 miles)	44.9	18	19	2	5	44

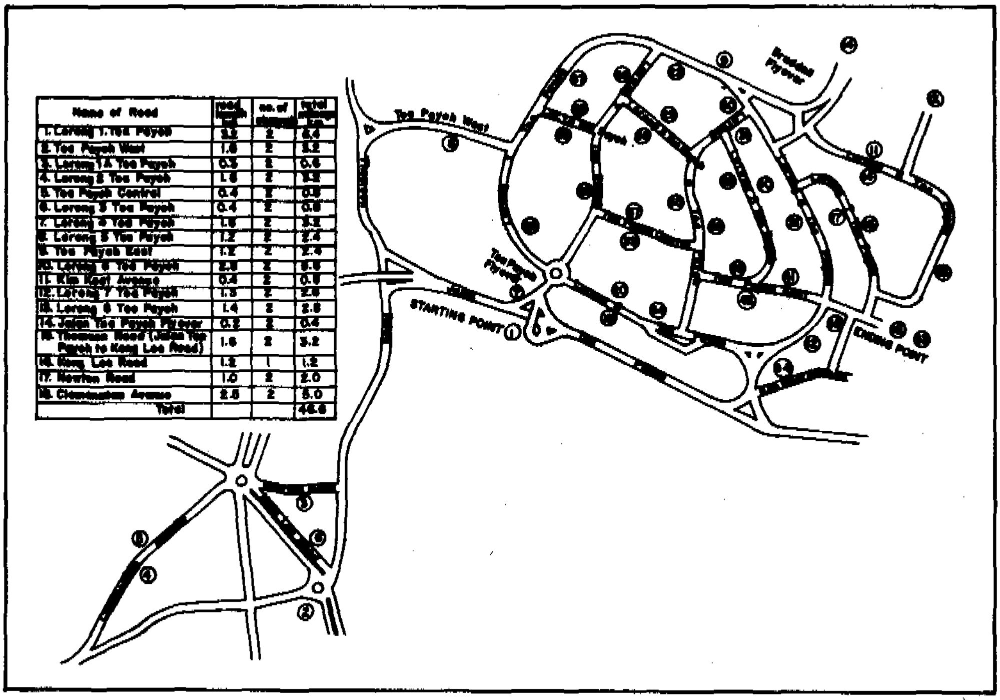
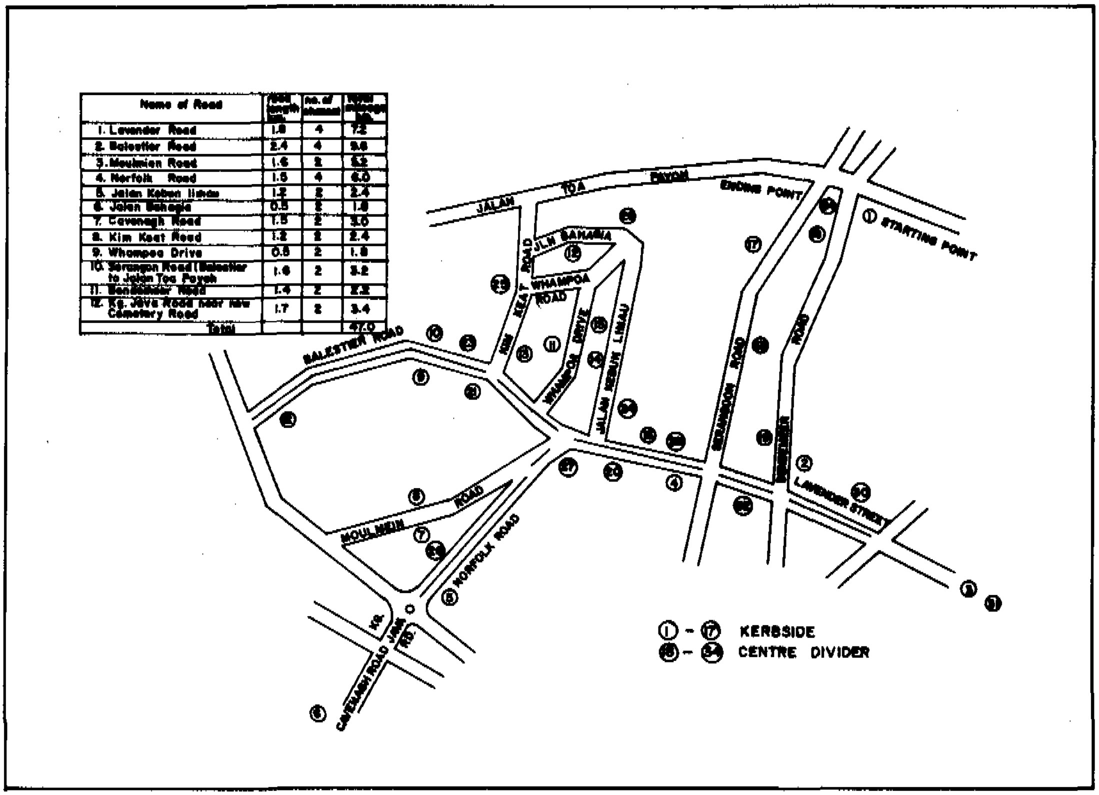


Fig. 1. Mechanical Sweeper Routes E1 (A.M.) All Kerbsides



Name of Road	Road length km.	no. of [illegible]	Total mileage km.
1. Lavender Road	1.8	4	7.2
2. Balestier Road	2.4	4	9.6
3. Moulmein Road	1.6	2	3.2
4. Norfolk Road	1.5	4	6.0
5. Jalan Kebun Limau	1.2	2	2.4
6. Jalan Bahagia	0.5	2	1.8
7. Cavenagh Road	1.5	2	3.0
8. Kim Keat Road	1.2	2	2.4
9. Whampoa Drive	0.8	2	1.8
10. Serangoon Road (Balestier to Jalan Toa Payoh	1.6	2	3.2
11. Bendemeer Road	1.4	2	2.8
12. Kg. Java Road near new Cemetery Road	1.7	2	3.4
Total			47.0

Fig. 2. Mechanical Sweeper Routes E17 (P.M.)

PROBLEMS ENCOUNTERED IN MECHANISATION

Basically, the problems encountered in the mechanisation of street cleansing in Singapore can be summarised into 3 categories — physical, human and mechanical. In view of the inter-dependence of the 3 factors for attaining high productivity, efficiency and effectiveness of street cleansing, it is paramount that a harmonious combination of the factors be established. Below is an evaluation of the problem posed by each of the factors.

Physical Factor

The physical factor can be defined as those inconveniences or hazards posed by physical constraints which hamper, restrict or prevent the smooth operation of the mechanical sweepers. In this context, the most notable problem plaguing mechanisation of street cleansing in the republic is the perpetual obstruction by vehicular traffic which has increased from 262,879 motor vehicles in 1973 to 289,954 in 1977, despite stringent measures taken by the Government to curb this proliferation. This has entailed frequent road congestion, a higher number of roadside car-parks and has generally increased the incidence of parking in urban and rural areas.

Although the problems vehicular obstructions pose to mechanisation is a global one, no feasible solution has yet been found. The building of car-parks in multi-storey edifices, though possible, is not practical in Singapore as land space is scarce and expensive. The problem has been accentuated by the recent implementation of mechanisation of street cleansing in residential housing estates where the roads are invariably narrower.

The solutions to the problem applicable to Singapore are:

- To carry out an in-depth study of the traffic trends of congested areas and to plan and deploy mechanical sweepers during periods when the traffic volume is mininal; and

- To employ more compact mechanical sweepers with high degree of manoeuvrability.

Another important physical constraint, more peculiar to Singapore, is the ubiquitous presence of trees along kerbsides of roads and centre road dividers. They are a menace as low overhanging tree branches not only cause physical damage to vehicles but also hinder sweeping. The situation has deteriorated following the Government's call to transform the republic into a green and salubrious island. However, the problem is now under control through the judicious planning of tree planting and continuous pruning of overhanging tree branches by the Parks and Recreation Department.

Not all metalled roads, particularly those in the older parts of the Republic, are suitable for mechanisation. There are still a large number of roads which are unkerbed, others have irregular kerbsides and some obstructed by street furniture and protrusions. All these have made it extremely difficult to achieve proper and effective mechanical sweeping. This is further aggravated by the bulkiness of the mechanical sweepers presently in use.

Another operational problem mechanisation faces is the numerous restrictions on vehicular traffic flow, including mechanical road sweepers. This has entailed high unproductive travelling, low sweeping mileage, high cost of fuel consumption and faster wear and tear of vehicles. It is therefore imperative to carry out proper planning of mechanical sweeper routes to attain a smooth traffic flow. To accomplish this, field staff with intimate knowledge of the traffic flow and conditions of the localities have been co-opted into the planning team.

Yet another problem of a transient nature is the continuous and extensive silting of roads and highways caused by earth stemming from constructional activities. As mechanical sweepers cater best for roads under normal conditions, the sweeping of heavily silted areas has been found to be ineffective, generating a dust problem and occasionally causing accidents as a result of airborne dust

The Human Factor

In any organisation where large numbers of workers are employed, problems of manpower are most significant. This is applicable in the management of the mechanical sweeper unit. It is universally accepted that unless a conscientious and well-trained driver is employed, mechanical sweepers cannot be efficiently operated at all. Since the human element is paramount, it is essential that selection of mechanical sweeper drivers be carried out discriminatingly to ensure a healthy and reliable workforce which will be an asset to the organisation.

The desired qualities which can be utilised as a criteria in the selection of mechanical sweeper drivers are self discipline, conscientiousness and independence. It is imperative that drivers possess these qualities since the work performed by them is not tangible.

Mechanical sweepers are complex and sophisticated vehicles with innumerable operational parts and accessories which are freely accessible to drivers. As such, the risk of sabotage by dissatisfied workers is always there and this will be one of the management's primary concerns. However, in view of the harsh disciplinary action taken against saboteurs, this malpractice is a rarity in Singapore.

The manipulation of actual sweeping mileage is another malpractice indulged in by mechanical sweeper operators inspite the availability of free travelling as well as sweeping milometers in the new suction sweepers. Manual fiddling of the sweeping mileage meter has made monitoring of work performance futile and problemmatical. This malpractice can only be overcome by the incorporation of more robust sweeping mileage meters, physically inaccessible to drivers, to all mechanical sweepers.

The Mechanical Factor

The proper maintenance of mechanical sweepers plays an important part in ensuring maximum vehicle utilisation and to fulfil the basic objective of keeping roads and highways clean. Although total preventive maintenance is hard to attain, perhaps due to inadequate manpower and non-availability of spare parts and facilities, every effort should be made to ensure that a superficial lubrication programme be carried out. This is indispensable as mechanical sweepers, unlike other public cleans-sing vehicles, are complex and sophisticated machines and any prolonged neglect in maintenance may lead to premature failure of parts and increase the downtime of vehicle utilisation.

In Singapore, the repair and maintenance of mechanical sweepers is carried out both at the centralised vehicle workshop of the ministry and in the respective depots. The former is responsible for all major repairs and maintenance including monthly servicing while the latter takes care of daily and weekly greasing, oiling, minor repairs and the painting of vehicles.

As cleanliness and lubrication forms the basis of good maintenance, every effort has been made by the management to ensure that routine lubrication programmes as recommended by the manufacturers are stringently adhered to and that vehicles are washed after every shift. Washing of vehicles is carried out by the respective drivers who are paid a washing allowance. The principal parts of the mechanical sweeper washed are the external body, rear body compartment, wire mesh filter, the auxiliary engine and the brush mechanism which is essential if vehicle breakdowns and corrosion is to be minimised.

During washing, any foreign matter such as pieces of wire, string or rags which have become entangled with the sweeping equipment are removed. Drivers are also responsible for cleaning the air filters of the main and auxiliary engine after every shift by hosing with pressurised air jets. This is necessary because a considerable amount of dirt and dust is churned up and thrown into the engine compartment during the sweeping operation.

In conjunction with washing and as an integral part of good maintenance, painting is continuously carried out in the depots to maintain the physical appearance of the vehicles. Painting serves to retard the rate of corrosion of the bodywork and boost the morale of the drivers. But, more importantly, it enhances the status of mechanisation of street cleansing and the image of the ministry as the public cleansing authority.

It is common knowledge that the amount of wear and tear of mechanical sweepers is very much dependent on the manner they are handled. As such, sympathetic driving should be encouraged among drivers and that only good and knowledgeable drivers be chosen to avoid excessive maintenance and repairs to vehicles. In this connection, all mechanical sweeper operators are required to attend short training courses held periodically at the centralised vehicle workshop to upgrade their driving skills and knowledge.

All mechanical sweeper drivers are also responsible for the thorough checking of the cylinder oil, hydraulic oil, battery water, and sweeping mechanism of their vehicles before proceeding to work as part of good preventive maintenance. As an added incentive, monetary awards with certificates of appreciation are given twice yearly to deserving and outstanding drivers who excel in all aspects of their work which includes high work productivity and meticulous care of vehicles.

In the respective depots, technicians, mechanics and welders form the backbone of the maintenance team who is responsible for all the practical aspects of vehicle maintenance and repairs. However, greater emphasis on regular maintenance requirements coupled with inadequate manpower will undoubtedly be in direct conflict with operational availability and utilisation rate of mechanical sweepers. As such, it is important that a balance to allow for maximum maintenance and minimal disturbance to operational availability and utilisation rate be achieved and maintained.

ECONOMICS OF MECHANISATION OF STREET CLEANSING

Prior to the implementation of mechanical sweepers in Singapore, the work of street cleansing was solely carried out by manual labour. The manual labour force which comprised daily rated workers was not only responsible for street cleansing but also a host of other related activities such as desilting of roadside drains and scupper holes, the sweeping of pavements, cycle tracks, pedestrian malls and collecting litter along their beat. Each individual worker was allocated a beat of certain length depending on the character of the beat area.

The introduction of mechanisation entailed a decrease in each labourer's workload and to maintain their work productivity, beat lengths were subsequently increased. In street cleansing work generally, either manually or otherwise, the unit cost or work measurement cannot be satisfactorily quantified as the efficiency of any street cleansing precess is a matter of subjective judgement. However, cost savings following the implementation of mechanised street cleansing can be computed from the difference between expenditure incurred on manpower and mechanical sweeper requirements before and after inauguration of mechanisation.

Recent case studies carried out by the Ministry of the Environment to assess the economic viability of mechanical sweepers for street cleansing after 5 years of implementation from 1973 to 1977 showed that substantial cost savings of some S$1,500 (US$690) per day or S$570,000 per year was achieved through mechanisation. The equivalent deployment ratio between men and a machine is in the region of 16:1.

Regular maintenance of mechanical sweepers to mitigate premature vehicle breakdowns is an economic factor worth considering. Another area where economy could be exercised is fuel consumption. This is attainable by proper planning of mechanical sweeper routes which should be aimed at achieving optimal sweeping mileage and minimal unproductive travelling i.e. increasing the productive mileage factor which is the percentage of actual sweeping mileage over total running miles. Indirect benefits from high productive mileage factor includes less wear and tear to vehicles, low maintenance and high vehicle utilisation.

RECOMMENDATIONS

The following recommendations are applicable to public cleansing authorities with or without mechanical street cleansing facilities.

In the selection of the types of mechanical sweepers, the parameters which warrant major considerations are the character of the roads in the area to be swept and the prevailing traffic conditions. This will not only ensure maximum utilisation of vehicles, but also high efficiency and effectiveness. Where narrow roads within residential housing estates or heavily congested areas are proposed for mechanisation, preference should be given to a highly compact and manoeuvrable vehicle. On the other hand, where mechanisation is desired for main roads and highways, bulky and robust vehicles incorporating higher suction power would be more appropriate in terms of efficiency, effectiveness and economy.

The overall performance of mechanisation is determined wholly by the competency and reliability of the mechanical sweeper drivers. As the human factor is paramount in governing the efficiency and effectiveness of mechanisation, it is vital that the selection of drivers be carried out discriminatingly. In Singapore, problems of manpower still pose a mammoth obstacle in the management of mechanical sweeper units.

In order to achieve high work productivity and fuel economy, planning of mechanical sweeper routes should be meticulously carried out with the aim of attaining a smooth traffic flow.

Constant and intimate liaison should be encouraged and maintained between the various authorities responsible for tree planting and pruning, road construction and public cleansing so that problems which hinder sweeping can be discussed and the steps taken to overcome them be jointly formulated to smoothly achieve the various objectives of the departments.

As mechanical road sweepers are rigid in their application, they cannot totally replace manual labour which is still required to cover such work as desilting drains, clearing scupper holes, sweeping cycle tracks, collecting litter and cleansing other inaccessible areas. Cleansing by manual labour can take the form of individual beat system as practised in Singapore or by gang-work.

CONCLUSION

It has been shown that the replacement of manual labour by mechanical sweepers for street cleansing in Singapore has been a viable proposition which has helped overcome the shortage of manual labour attributable to the growing affluence of the nation.

However, it must be realised that the full benefit of mechanisation in terms of efficiency, effectiveness and economy can only be attained if administrative action is taken to ease traffic restrictions on mechanical sweepers, exercise stringent controls over the parking of vehicles and to acquire more suitable types of mechanical sweepers.

The demand for mechanical street cleansing in the republic has grown in recent years and has come to stay as more and more roads and highways are being planned and developed to improve the communication network.

Finally, it can be said that the introduction of mechanisation of street cleansing has added a new dimension to the public cleansing services by upgrading the standards, status and safety of street cleansing in Singapore.

MANAGEMENT OF A REFUSE DISPOSAL GROUND

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INTRODUCTION

Solid waste disposal is a basic and universal problem which besets not only developed countries but the rest of the world as well. Explosive population growth coupled with extensive development of industries has generated more waste thus imposing a financial burden on governments for the sanitary collection and safe disposal of waste.

We are all aware that the nature of refuse varies widely throughout the world. Among the factors for such diversification are climate, the extent of industrialisation and living standards. Even within the boundaries of a small country, there may be important variations in the quality of refuse collected.

Owing to climatic and social conditions, Singapore has had to provide a daily collection and refuse disposal service.

SOLID WASTE DISPOSAL ADMINISTRATION IN SINGAPORE

Singapore is administratively divided into 7 health districts under the Environmental Public Health Division of the Ministry of the Environment. Each health district is under the charge of an assistant commissioner of public health. The responsibility of street cleansing, collection, transportation and disposal of solid waste comes under the respective health districts. The Engineering Services Department of the Environmental Engineering Division of the ministry provides necessary engineering support to the health districts to enable them to carry out their responsibilities and duties effectively.

Domestic and trade premises in Singapore generate a daily average of 1,393 tonnes of refuse. Industries discharge about 430 tonnes and Government offices another 140 tonnes of refuse a day.

Waste from all the combined sources are collected daily by 259 refuse vehicles. Two hundred of these vehicles are especially built refuse collectors fitted with a compaction mechanism and bin lifting devices.

The refuse vehicles operate from the respective 7 health district depots strategically located to service the entire island state. They are out at the break of dawn and return in the afternoon for daily cleansing maintenance. Some of these vehicles are required to perform two shifts. The collection routes of these vehicles are carefully planned and reviewed periodically to increase the productivity of the refuse collection vehicles and crew.

The refuse collected is disposed of at two refuse disposal grounds under the authority of two health districts, one located on the eastern and the other on the western part of Singapore.

Based on March 1978 figures, the daily average tonnage of refuse collected from the whole country was 1,963 tonnes and these were disposed of as indicated in Table 1.

Table 1. Daily Disposal of Refuse

System	No of Plants/ Disposal Grounds	Tonnage disposed of	Percentage
Landfilling at Disposal Ground	2	1,929	98.27%
Composting	1	24	1.22%
Incineration	1	10	0.51%

Both the refuse disposal grounds in Singapore are tidal swamps and the pollution control measures instituted at the disposal ground are as follows:

- Effective bundwalls have been built and maintained to prevent the pollution of existing and neighbouring water-courses;

- Reduction of moisture content in refuse due to rainfall is by ensuring refuse bins are covered and refuse bin compounds are roofed over in order to minimise leachate formation; and

- Tipped refuse is effectively covered with earth daily to control leachate formation, water pollution, smell, fly breeding and other public health hazards.

MANAGEMENT OF A REFUSE DISPOSAL GROUND

The functions and work involved in the management and operation of the disposal grounds can be broadly categorised into the following:

Provision of Dumping Grounds

Under our system, the Engineering Services Department provides the necessary engineering supporting service and is involved in the following areas of activity:

- Projection of land requirements, acquisition and clearance of land.
- Planning - setting broad guidelines on the utilisation of the land, such as the area where dumping should initially commence and the demarcation of the land into phases for progressive dumping.
- Preparation of land for dumping, including the development of infrastructure such as metalled access roads, bridges, earth bunds, major drainage, weighbridge offices, garage sheds for heavy machinery, stores, toilets, washbays for vehicles and security fencing as well as marking out fill-boundaries of the land for refuse disposal.
- Maintenance work such as repairs to metalled access roads, bridges and facilities.
- Provision and repair of heavy machinery such as bulldozers, compactors and motor-graders.

Planning of Dumping Plots

The disposal ground follows the grid system of refuse tipping. This system consists of dividing the layout plan of the land into square grids which each in turn is sub-divided into 4 sub-grids. These grids are given alphabetical and numerical references for the location to be identified.

The location where refuse dumping is being carried out will then be indicated on this grid plan and after the day's operation, the whole grid or the area of it which is tipped with refuse will be shaded off. This system serves to control the orderly dumping of refuse, the scheduling in the utilisation of plots and monitoring of available dumping plots so that early planning and preparation of a new site can be carried out systematically.

Dumping of refuse in a new area has to be carried out at a pre-determined site. The site chosen is normally at the end of the access metalled road that leads to the new area. However, advanced preparation of the dumping site (tipping platform) is required before actual refuse tipping can be carried out. This is to ensure that the dumping site is adequate in size and compacted enough to cater for the volume of traffic during full-scale dumping operations.

Daily Operations at a Disposal Ground

The management of daily operations at a disposal ground and its work processes are shown in Fig 1.

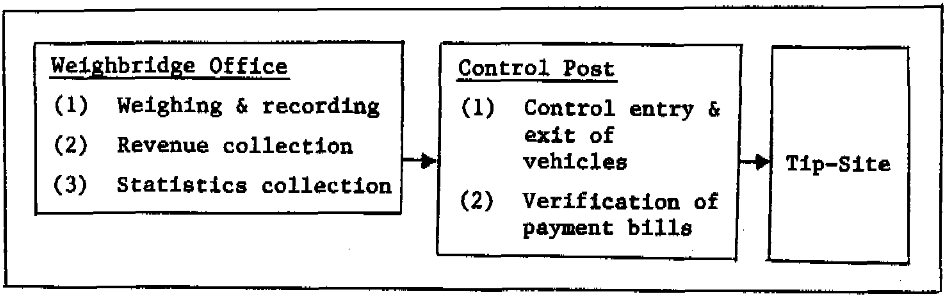

Fig. 1 Diagramatic Flow Chart

The detailed functions and duties of these key areas can be broadly categorised under three headings – weighing, recording and revenue/ statistics collection; control post; and tipping operation.

The refuse disposal ground fee was introduced at the disposal grounds on March 1, 1976. The fee for each trip of the vehicle as prescribed in the Environmental Public Health (Public Cleansing) (Amendment) Regulations, 1976 is as in Table 2.

Table 2. Fee for Refuse Collection

Refuse Load	Rate of Fee
Not exceeding one tonne	No charge
Exceeding one tonne but not exceeding two tonnes	S$10 (US$4.6)
Exceeding two tonnes	$3.50 per half tonne or part thereof

All vehicles arriving at the disposal grounds must first be weighed at the weighbridge. For all vehicles except those from the Environmental Public Health Department and other government departments, the weighbridge operator is required to complete the relevant form for billing (in duplicate). This form shows, among other things, the weight of the refuse to be disposed and the fee payable. The refuse disposal fee must be paid in cash at the weighbridge office, except for private firms which have given bankers' guarantees or made advance cash deposits with the department. Quasi-government bodies are billed monthly and are not required to furnish bankers' guarantees or cash deposits.

For cash payments only, the vehicle's number, the driver's name and weight of the refuse are entered in the forms for billing. The driver pays the fee to the cashier at the weighbridge office. The cashier returns the original form stamped "PAID" together with a receipt to the driver. The duplicate form is retained by the cashier. With the stamped upper portion of the form and the receipt, the driver proceeds to the control post of the disposal ground.

Where payment is made monthly, all the particulars are entered in the form for billing. The weighbridge operator stamps and signs the form and hands over the original copy to the driver of the vehicle. With this endorsed form, the driver proceeds to the control post.

Earth supply from contractors for the covering of refuse; granite (crusher-run) for the building of roads and items salvaged from the site are also weighed and recorded. Statistics are gathered and compiled daily.

The officer-in-charge controls the entry of vehicles into the tip-site at the control post. All originals of forms for billing and exemption memos are endorsed indicating that refuse has been dumped by the officer-in-charge. All such documents, except those for which cash payment has been made, are collected at the control post. The officer-in-charge keeps records of dates and serial numbers of all documents and records the time that the Environmental Health Department's vehicles leave the disposal ground in the vehicle time sheet.

Refuse trucks reach the controlled tip-site along a prepared track and reverse on firm compacted refuse covered with earth and laid with granite (crusher-run). Sufficient space is available to accept vehicles without delay.

Any refuse that has not been compacted in a refuse collection truck, bulky items, furniture and crates, etc. are discharged and crushed by bulldozers or landfill compactors. Together with the mascerated refuse delivered for disposal by the refuse collection vehicle, they are pushed to the far end of the tip and spread in shallow layers. Each layer is thoroughly compacted by the bulldozers and landfill compactors over the entire working front. Each day's refuse is thoroughly compacted by the end of day's work which is from 6.30 a.m. to 6.30 p.m. in 2 shifts. All refuse is covered as soon as it is practical and at least by the end of each day. It is apparent that in the life of a disposal site some bad weather will be encountered. We have space available close to a well constructed site road for use during adverse conditions.

The problems associated with the disposal of industrial waste have recently been highlighted, particularly with regard to toxic chemicals. Industrial wastes form a part of the dumping which unlike domestic or trade waste, cannot be treated alike as they have to be inspected carefully for any health, fire and pollution hazards before they are disposed of.

The following are examples of industrial waste at present dispose of by private disposal services in the disposal ground. This refuse requires our special attention:-

Woodwaste: This is normally brought to the disposal ground from wood-working industries. As it poses a fire hazard, such waste is tipped separately from the rest of the refuse.

Oil waste: This type of waste comes normally from shipyards and is mixed with sawdust and buried away from other waste in order to prevent it from polluting the water sources.

Chemical waste: Only inert or otherwise innocuous materials are accepted. Prior approval in the form of a permit has to be obtained for the disposal of chemical waste. Applicants are required to furnish all the relevant dates and information relating to the waste to be disposed of. Such information must include the manufacturing process, the properties, composition and quantities of the raw materials used as well as the properties, composition and quantities of the waste to be disposed of. Where the chemical waste is in the form of slurry or sludge, pre-treatment must be carried out before disposal. Such pre-treatment may include de-watering, de-toxicating and the encasing of such toxic wastes in steel containers, with or without a lining of concrete or bitumen.

Abattoir waste: Abattoir residue and carcases and condemned food articles are buried in the tip under supervision.

Health and Pollution Control

Generally, health hazards or nuisances from the disposal ground are smells, flies and rodents, fire and dust.

The measures presently used to control smells, flies, rodents and fire at the disposal ground are a daily earth covering of the tipped area. Dust is normally due to heavy vehicular movements along unmetalled access roadways during dry weather. This nuisance is minimised by the regular watering down of the unmetalled roadways by a water wagon and landscaping plantings and turfing over the tipped area.

Safety Measures for Staff and Property

The disposal operations themselves present safety hazards to both site employees and users. There is constant vehicular activity and therefore many chances for collisions between vehicles, landfill equipment and people on foot, especially during adverse weather conditions.

Staff and workmen in the disposal ground are provided with appropriate safety equipment approved by the Safety Committee of the ministry.

Although there are no special periodical medical checks on the staff and workmen in the dumping grounds, these personnel are entitled to free medical examination and treatment as and when the need arises.

A 24-hour security watch is maintained at the disposal ground. Security fencing and proper stores are provided. Fire fighting equipment is installed and the officers-in-charge of the disposal ground are trained for isolated fire-fighting.

Recovery of Waste for Re-use

The present arrangement undertaken by the annual salvage contractor at the disposal ground consists of the recovery and re-use of all non-ferrous scrap metal; all ferrous scrap metal including empty tin cans and other empty metal containers ferrous origin; all empty glass bottles and broken glass; and all waste-paper and cardboard.

CONCLUSION

There is no global solution to the problem of refuse disposal and there is also no single best method. Any of the prevailing main methods or a combination of them can be used but the method or methods adopted must be suited to local circumstances. Consideration should, as far as practicable, be given to the recovery of materials for re-use. With good management, no risk to public health is likely to arise from refuse disposal by landfilling. Although this method of refuse disposal is satisfactory, its drawback is that it requires large areas of land.

As far as land-scarce Singapore is concerned, disposal by incineration is considered the most cost-effective method. As the best method of volume reduction, it reduces refuse down to 10 per cent of its original volume. These remnants comprise ashes and residue which are inert and innocuous and can be disposed of quite easily as landfill.

The technology of incineration has developed over the decades to a sophisticated level of efficiency. Modern incinerators are clean and highly mechanised. Complete combustion is almost assured and with adequate gas-cleaning equipment, such as electrostatic precipitators, air pollution is kept under control.

Singapore's first refuse incineration plant capable of burning 1,200 tonnes of refuse daily (or 61.0 per cent of the present daily refuse output) was expected to be commissioned in late 1978. It would initially have three furnaces or incinerator units with integrated boilers; each capable of burning 400 tonnes of refuse in 24 hours.

Under this method, refuse trucks will unload refuse into a large bunker. The refuse will be picked up by grab-cranes and fed into each of the three incinerator units.

Each unit consists of a roller grate stoker. The burning refuse will move steadily downwards by the rotating movement of the grates. Primary combustion air will be drawn from the bunker, pre-heated and introduced into the furnace through the underside of the rotating grates.

The walls of the furnace comprise gas-tight, welded-membrane tubes, water-cooled by natural circulation. Heat transfer by radiation and convection will take place as the flue gas flows through the boiler passes.

Superheated steam from the boilers will be expanded in a back pressure turbine, which together with the generator, will produce 11 megawatts of electricity. Part of the electricity will be used to operate the plant and the surplus sold to the Public Utilities Board, a quasi-government body producing electricity for the consumers.

Ashes and residue from the burnt-up refuse will be transported to an ash pit via a vibrating conveyor. On its way to the ash pit, ferrous metals will be picked up by overhead electro-magnetic separators. The salvaged metals will be pressed into bales and sold as scrap.

RE-ROUTING OF REFUSE COLLECTION ROUTES IN SINGAPORE

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INTRODUCTION

This report is intended to provide an overview of the refuse collection system in Singapore, with particular emphasis on the method of re-routing existing refuse collection routes. Some of the central problems encountered in planning for a viable system of routes will be highlighted.

In planning for a workable system of refuse collection routes it is essential that the anticipated rates of refuse output and types, the frequency and times of collection, the constraint of manpower and refuse collection vehicles and the type and capacity of the bins be considered. The refuse removal service should be sufficiently frequent to prevent objectionable accumulation or overspilling of contents of refuse storage receptacles.

In Singapore, some 1,963 tonnes of refuse are generated daily. 1,394 tonnes or 71 per cent consists of domestic and trade refuse and is removed daily by the Environmental Health Department of the Ministry of the Environment. The daily refuse removal service, which includes Sundays and public holidays, is achieved through a continually up-dated system of refuse collection routes. In certain bin centres and urban trade premises which involve a high rate of refuse output, it is necessary for the bins to be emptied twice a day.

TYPES OF REFUSE

Three types of refuse are distinguished: domestic and trade refuse, institutional refuse and industrial waste.

Domestic and trade refuse is the type generated from residential premises, hotels, shops, commercial premises, markets and hawker centres. Institutional refuse comprises tree cuttings, condemned goods, construction wastes and office waste produced as a result of governmental activities. These are removed by the respective governmental departmental vehicles. Industrial waste is a by-product of industrial activities and includes wood-waste, sludges, carbides, construction waste and bulk refuse. These are removed by private contractors.

ENVIRONMENTAL HEALTH DISTRICTS

The island proper is divided into 7 Environmental Health Districts which administer all environmental health functions from their respective depots. Each depot has been allocated its quota of refuse collection vehicles and these vehicles are responsible for collection of refuse from the district for disposal at the two dumping grounds.

REFUSE BINS

The capacity of the refuse storage receptacles used are related to the likely content. There are four sizes - 85, 170, 255 and 1000 litres. Refuse from trade and domestic premises is mainly disposed of in 85-litre, galvanised mild steel carrier bins. 85-litre plastic bins are also used and these have the advantage of being lighter and quieter to handle.

The 170 and 255-litre bins are the older types of metal bins which are mainly used in the Environment Ministry's bin centres in the rural districts. The numbers in use are however small and these are gradually being phased out and replaced by the larger capacity 1,000-litre bulk bins which are provided with castors so that they can be wheeled to the refuse collection vehicle.

The bulk bins are suitable for coupling to the bin-lifting mechanism of the compaction, rear-loading type of refuse vehicles. The bins can be lifted and emptied in one operation. This has been found to be the most efficient way of removing bulk refuse. The larger capacity of the bulk bins results in a higher tonnage of refuse removed per unit time as compared with removal using the other types of bins. This time saving permits more trips to be operated per shift.

REFUSE COLLECTION VEHICLES

There are basically 3 different types of refuse collection vehicles in use, namely side-loaders with compaction devices, enclosed rear loaders with compaction devices and crane vehicles which are open and are not provided with compaction devices. Table 1 summarises the types and numbers of vehicles in use.

The vehicle fleet of 259 refuse collection vehicles is required to operate 222 refuse collection routes daily. 171 routes are operated in the morning shift and the rest in the afternoon. The crane vehicles have gradually been phased out and are only used to remove refuse from bin centres where the 170 and 255-litre refuse bins are still being used

Table 1. Numbers and Types of Refuse Collectors in Use

Type	Number	Percentage
a) Side loaders	56	21
b) Rear loaders	165	64
c) Crane Vehicles	38	15
Total	259	100

or when the approach roads to the bin centres are too narrow for the other types of vehicles to negotiate. The payload of the refuse vehicles are in the range 3.2 to 6 tonnes.

TYPES OF REFUSE COLLECTION ROUTES

It is possible to distinguish between three types of routes depending on the nature of refuse collection points covered. These are the direct, indirect and mixed routes.

Direct collection routes are routes whereby refuse is collected from individual premises. This includes houses and bungalows, shophouses and trade premises. The refuse storage receptacles used are the 85-litre type and these are placed at the kerbside. This mode of refuse collection is normally the most time-consuming as the refuse is removed from numerous low refuse tonnage premises. Consequently in most of the districts, only one trip is operated per shift. In some districts it is possible to operate two trips per shift as the area covered by the route is near to the dumping grounds. These routes are normally served by side-loaders.

In indirect collection routes, refuse is removed from bin centres. This refuse is mainly from the housing and development board (HDB) and Jurong Town Corporation (JTC) flats, markets and hawker centres. Refuse and silt from drains is also carted to the bin centres by street cleansing labourers. The refuse storage receptacles used at these bin centres are mainly 85-litre and 1000-litre bulk bins. Routes covering these bin centres are normally served by the rear-loading compaction vehicles. The crane vehicles are used to serve bin centres where the 170 and 255-litre bins are in use. The on-board crane is suitable for lifting these bins which can be quite heavy when fully loaded.

Mixed routes, as the name implies, are routes having direct and indirect collection components. These are normally served by rear-loading compaction vehicles. A summary of the types of routes operated is given in Table 2.

Table 2. Numbers and Types of Refuse Collection Routes

Types	REFUSE COLLECTION ROUTES			Percentage
	am	pm	TOTAL	
a) Direct collection	51	20	71	32
b) Indirect Collection	61	25	86	39
c) Mixed Collection	59	6	65	29
Total	171	51	222	100

RE-ROUTING EXERCISE

The accelerated pace of development and change in the republic and the continual modernisation of the vehicle fleet means that refuse collection routes will have to be reviewed constantly. The growth of new housing and private residential estates requires the extension of refuse collection services. Changes in refuse sources resulting from shifts in population density and the phasing out of bin centres require that the refuse routes be updated.

The re-routing exercise is carried out for each district with a view to achieve three basic objectives. Firstly to maximise the refuse loading per trip without exceeding the payload rating. In particular, under-utilisation of the vehicle, as for instance when it collects less than its capacity in the allotted working time is avoided. A capacity of 90 per cent of the payload rating is normally aimed at to allow for fluctuations in the daily refuse output.

The second objective is to reduce the distance travelled by the refuse vehicle by minimising unproductive travelling. This requires up-to-date information about the nature of the roads and the traffic system and conditions in the area designated for the routes. The third objective is to boost the number of trips per shift. This is achieved by maximising the number of trips without stretching the working hours beyond the allotted time.

Data on the performance of existing routes over a six-month period are obtained in the format as given in Table 3. These are analysed to give an indication of the average refuse tonnages, the shift times and the likely fluctuations in refuse output for the various routes. Projections of anticipated refuse output from new areas in the district that are being developed are also obtained.

Where an existing route conforms to the optimising objectives, no changes are made.

If the problem of overloading arises, precipitated for instance by additional refuse sources resulting from the growth of existing housing and private residential estates, certain collection points would be taken off and assimilated into adjacent routes.

Table 3. Feedback on Route Optimisation

DISTRICT: ______________________ ROUTE REF: ______________

VEHICLE REG: ___________________

S/No	Date	TIME			LOAD (TONNES)			Total tonnage (Tonnes)	Remarks
		Out	In	Diff	Trip 1	Trip 2	Trip 3		

In the case of underloading, an attempt is made to include collection points of high refuse output and consider them vis-a-vis the other related objectives.

New sources of refuse would normally be accomodated by existing routes and new routes could be created if deemed necessary.

A two-shift system has been employed for the refuse routes. The shift factor F, defined as the ratio of the total number of routes to the number of morning routes has been maintained in the region of 1.20 - 1.35 to allow sufficient downtime for maintenance of the vehicles.

Statistics on the vehicle downtime for the past 12 months are studied to establish the average figure. The size of the active vehicle fleet which can be deployed for each shift is worked out based on this figure. This forms the basis for ascertaining whether the overall vehicle fleet is sufficient for deployment purposes under the re-organised routes' operational programme.

All routes served by rear-loading compaction and crane vehicles employ 3 crew members (excluding the driver except for the side-loaders where 4 crew members are required.

A schedule of the routes to be operated is drawn up giving pertinent information on the type, registration number and payload of the refuse collector to be used, the number of crew members, the order of collection, the location and approximate time of arrival at each collection point, the number of domestic and non-domestic premises served by the collection point, the size and number of refuse bins to be collected and the dumping ground to be used. The format of a typical route schedule is given in Table 4.

Table 4. Typical Route Schedule

ROUTE REFERENCE: ____________ DATE: ____________

CREW (EXCLUDING DRIVER): ________ VEHICLE NO: __________

VEHICLE MAKE: ______________ PAYLOAD: ____________

S/No	Location	Arrival Time	NO OF PREMISES		NO OF BINS				Remarks
			Domestic	Non-Domestic	85 l	170 l	255 l	1000 l	

The productivity of a refuse collection route is measured in terms of the tonnage of refuse removed per shift. The tonnage per shift measures both the carrying as well as the travelling capacity of the vehicle and hence the performance of the vehicle in the district. The effectiveness of a re-routing programme is gauged by comparing the productivity figures before and after re-routing. The format for such a comparison is given in Table 5.

PROBLEMS IN RE-ROUTING

Removal of refuse from areas in the Central Business District involving heavy vehicular traffic poses some operational problems. In such areas collection will have to take place before or after the congested periods. This additional constraint will mean that the vehicle may be compelled to do a certain amount of unnecessary travelling just to remove refuse from pockets of premises before or after the peak traffic. This necessitates a compromise.

Table 5. Comparison of Route Performance

ROUTE PERFORMANCE ______________________ DISTRICT

			BEFORE RE-ROUTING					AFTER RE-ROUTING				
S/No	Types of Routes	Total No of Routes	Total No of Trips	Total Daily tonnage	Average Tonnage /Trip	Fluctuations Max (+) Min (-)	Total No of Routes	Total No of Trips	Total Daily tonnage	Average tonnage /trip	Fluctuations Max (+) Min (-)

The output of refuse from trade premises tends to fluctuate fairly widely, approaching a low during the weekends. This trend is also shown by output of refuse from domestic premises though the fluctuations are less substantial. This results in lower productivity figures for the weekend shifts and is particularly so for the urban districts.

The refuse output usually displays seasonal variations with peaks coinciding with the fruit and festive seasons. This seasonal increase in refuse output is normally not planned for in the re-routing exercise. The excess refuse will have to be removed by additional vehicle trips, planned on an ad hoc basis.

In certain areas the access roads to the bin centres are narrow, limiting the accessibility of these collection points to smaller refuse collection veiicles. This imposes an additional constraint on the planning of the routes.

A number of the bin centres are still using the 85-litre carrier bins. These are points of large refuse output and the multiplicity of the smaller receptacles considerably increases the haulage time.

CONCLUSION

Refuse collection routes have to be up-to-date for operational reasons. Lead time in the planning process are obtained by allowing for new sources of refuse from areas that are being developed.

At present the approach used in the re-routing of refuse collection has been practical and simple. A more elaborate technique which out as an aid to efficiency in refuse collection by prescribing the best method for the job. A computer model representing all the separate activities of the refuse removal service can be set up. This can throw light on the results which will be obtained by varying the factors involved such as the quantities of refuse, the types of premises, deployment of vehicles and men.

FLEET MAINTENANCE OF VEHICLES UTILISED IN THE COLLECTION AND CONVEYANCE OF SOLID WASTE

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INTRODUCTION

The Ministry of the Environment, Singapore, operates a fleet of 259 refuse vehicles of which 221 are of the compaction type. This fleet is distributed over 7 depots which are responsible for the collection of refuse in their respective sectors. A centralised workshop is kept to cater for major repairs.

The maintenance organisation is divided into 3 levels, the depot, workshop and contractors.

At the depots, daily checks are made by the drivers themselves and weekly checks are made by technicians and technical officers. Daily checks by the drivers ensure that the vehicles are in a roadworthy condition before they move out. As part of the maintenance programme, training of drivers is conducted by a very experienced senior officer of the centralised workshop and we shall come to this point later. Minor defects detected by the drivers are corrected by the depot mechanics immediately. If the defects are major, the vehicle will be scheduled for the workshop.

Also in the depots, a weekly lubrication programme is carried out under the supervision of technicians and technical officers who cannot a short inspection and a road test after the lubrication is done. This weekly check serves to ensure that the drivers carry out their daily tasks.

The centralised workshop conducts regular servicing and a preventive maintenance inspection every 40 days. This serves as a check on the effectiveness of the depots' maintenance work. When the vehicles come into the workshop for this 40-day periodic servicing, a programmed change of parts based on the manufacturer's recommendations is carried out. The types of repairs peculiar to the particular model of vehicle are constantly monitored and parts are changed before failures occur.

Also, complete repainting of the vehicles are done in the third and sixth year of the vehicles' lives and this spray-painting is done when the vehicles come in for their 40-day periodic servicing.

During the inspections, both at the depots and at the workshop, vehicles with major faults are screened out. Repairs are done at the workshop and are also farmed out to outside contractors.

PREVENTION OF BREAKDOWNS AND UNSCHEDULED REPAIRS

Breakdowns are expensive and very disruptive to the operations. This is especially so in our case because each refuse vehicle has a route to cover and a breakdown would mean that garbage on that route would not be collected, and garbage is extremely putrescible in Singapore.

To minimise such breakdowns we carry out the replacement of parts and sub-assemblies before failures occur, we use more durable components, undertake a meticulous observation of a 40-day lubrication and inspection programme, carry out driver training.

Scheduled Replacements of Parts

Unexpected failure of a component frequently damages other components which are otherwise serviceable and expensive. The key to the prevention of unscheduled repairs is proper records.

Every vehicle has a Vehicle History Card which is similar in concept to the medical history card kept by the family doctor. The Vehicle History Card records all the maintenance and repair done on the vehicle throughout its useful life and all the components that are replaced are also recorded. This card is also useful when it comes to the replacement of the entire vehicle.

The information in the Vehicle History Card is extracted from Job Cards. Each time that the vehicle comes into workshop for repair or maintenance, a Job Card is attached to the vehicle to record all the job done to it together with the list of spares used.

Our basic approach to scheduled replacement of parts begins with the manufacturer's recommendations. From this, we develop our own programme. This is necessary because most manufacturer's recommendations attempt to cover all the fleet operators and our own special requirements differ from such general recommendation in such respects as local operating conditions, vehicle age, level of maintenance, condition of the sanitary landfill and climate.

As it is not possible to come up with the right schedule the first time, we are continually reviewing the Vehicle History Cards and modifying our schedule for replacement of sub-assemblies, to take into consideration engineering improvements. Another point to consider is whether we can stretch the manufacturer's recommendations. The savings can be considerable.

Repairs and maintenance done in the workshop is not the only type of work recorded for study and analysis. Breakdowns on the road are analysed to determine the pattern of the road failures and these usually reveal the weaknesses of our maintenance programme. For instance, if our study of road failures indicates a pattern of clutch failures and unscheduled visits to workshop for clutch plate replacements, it means that clutch overhauls should be done at shorter intervals or perhaps a better quality clutch plate or a slightly larger-diameter clutch should be used. Also, if there is an unusually large number of requests for the breakdown team because of stalled vehicles, investigation may show plugged fuel filters and injection nozzles. Thus, a crash programme can be immediately launched to clear up the problem.

More Durable Components

While we conscientiously strive to change a component before failure occurs, we realise that time spent on the replacement of the part prevents us from maximising equipment utilisation. Thus, we try to reduce downtime and cost of repair by proper selection of components that have a longer service life.

40-Day Lubrication and Inspection Programme

The lubrication and inspection done every 40 days at the workshop is the second level of our maintenance programme - the first level of the programme is found at the depots. While equipment is becoming more sophisticated in design and new management theories are coming up to explain better maintenance schemes, the basics of a sound maintenance programme are unchanged-the three elements of a good programme are frequent inspection, regular servicing and thorough lubrication. Every 40 days, experienced workshop personnel will ascertain if the depots' maintenance are properly done and parts showing signs of failure are replaced.

Driver Training

We know that good and careful driving can do a lot to stretch the equipment efficiency. Thus, the training of the drivers from the depots is done by a senior officer from workshop. This officer, besides being a good driver, is a competent technical man.

PROBLEMS ASSOCIATED WITH DAMP REFUSE

In Singapore, the refuse is wet and hence it is relatively dense. It is very easy to overload the refuse vehicle with dense refuse and consequently, 4 major defects commonly occur. These are rapid wear of the clutch plate, failure of the rear-leaf springs, hair-line cracks on the chassis-frame and smoky exhausts.

Overloading of the refuse truck can be avoided if the maximum expected weight of the refuse to be carried is matched to the chassis used. Overload indicating devices can also be fitted. Another way of avoiding overloading is to use tandem-axle chassis, but a single-axle chassis is used in Singapore because of the lower capital cost.

With wet refuse, vehicles also have to be continually maintained to keep them water-tight. Sullage water that drips out onto the roads causes a smell problem. We change our rubber seals frequently and modify vehicles so that the tail-gates are clamped to the bodies positively.

Wet refuse also causes extensive corrosion to the equipment. We combat this by specifying continuous welds on all our equipment, which will be galvanized in future. The floorboards of future refuse vehicles will also be fabricated from 6 mm steel plates. Vehicles are also painted with corrosion-resistant paint to curb rusting. Adequate washing is essential to reduce corrosion. All the depots have high pressure water cleaning systems for the drivers to clean their vehicles daily.

CONCLUSION

To date, we have been tackling the maintenance of solid waste vehicles by identifying problem areas and formulating plans to curb the problems before they develop further. The results are gratifying our vehicle utilisation rate has gone up through the past years and we expect the trend to continue.

SANITARY LANDFILL APPROACH TO DISPOSAL OF MUNICIPAL REFUSE IN A DEVELOPING COUNTRY

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INTRODUCTION

Unwise management of solid wastes always causes both social and economic problems, such as the transmission of pathogenic micro-organisms, contamination of air, water and land, and shortage of resources.

Although man and his environment must be protected from the adverse effects of solid wastes, such wastes have never been a serious problem in a primitive or agricultural society. When recycling became inefficient in the modern world, more and more land and resources were needed to support increasingly concentrated populations. Developed countries first encountered the problem of solid waste disposal. Management of solid wastes has developed into an elaborate and sophisticated technology, but how to chose a proper method of disposal still affects government policy.

In a developing country, initial investment costs for solid waste disposal and co-ordination with manual methods of disposal according to the local social structure are particularly serious considerations for a government. In this report it is intended to suggest a sanitary landfill approach to the disposal of municipal refuse for a developing country.

REGIONAL SANITARY LANDFILL

Open dumping is the most primitive method of waste disposal. It is foul and brings complaints by residents around the dumping area. Sanitary landfill is far less disruptive to the environment and permits inexpensive biodegradation without much pollution, disease, or unsightliness. With proper ingenuity, landfill may reclaim wasteland or beneficially alter the topography of an area. So, properly engineered landfill is suitable for a developing country.

On the other hand, several problems are associated with sanitary landfill. How to avert both water pollution and the gas hazard is the most serious problem to be considered. But, economically and ecologically, landfill is still recommendable.

In Taichung in Taiwan, the refuse problem has become more and more acute in recent years. The local government wants the co-operation of personnel in health, education and environmental engineering to work with the government to propose, plan, design and develop a full-scale method of refuse disposal. Here, data for Taichung is used as an example to illustrate how to establish a regional sanitary landfill.

Taichung represents a developing city. The total 1978 population was about 560,000; a 10-year population projection is 1,000,000 persons. Solid waste is now produced at the rate of 300 tonnes a day. The area of Taichung is now 2,045 hectares but urban development plans are for a projected area of 16,342 hectares.

At the time of study, solid wastes were largely disposed of in open dumps. The government is determined to carry out a solid waste management plan and one of the recommendations is sanitary landfill. More costly processing and disposal methods are also under investigation however, even if other methods are chosen, it is felt that a large proportion of the total non-combustible waste will still remain to be disposed of on land.

CHARACTERISTICS OF SOLID WASTE

The composition of solid waste varies from country to country. In Taiwan, from the view of disposal, it can be divided into 4 categories: non-combustible rubbish, combustible rubbish, inorganic refuse (ashes), and garbage (Tables 1 and 2). Taiwan is a sub-tropical island of great population density (1978: 470 per km^2) and refuse content contains 44.8 per cent moisture in the dry season and more than 55 per cent in the rainy season. For this reason, incineration alone is not the answer. Some industries still use coal and solid fuel, therefore the ash content of refuse is very high, nearly 50 per cent of the total. Due to this reason landfill is suitable and this kind of treatment is favourable to the ecological balance.

In Taiwan the average daily amount of refuse per person is 0.4 to 0.6 kg; in rural areas the amount is 0.535 kg daily; while in the cities residential waste amounts to 0.42 kg daily. Large amounts of waste remains in water drains and sludge and only about 60 per cent of all waste can be collected. Tables 1 and 2 provide information on the nature and composition of solid wastes in Taiwan.

SITE SELECTION

The recommended site is at the southwest edge of the city because it is far away from water resources. This site is a hill some 100-200 metres high and the soil texture is reddish-brown lateritic soil lacking

Table 1. Urban and Rural Solid Waste Content of Taiwan

Area / Composition of Refuse	Taiwan rural district	Taiwan urban district
Garbage	24.7	17.3
Combustible rubbish	26.3	23.7
Non-combustible rubbish	7.6	5.2
Inorganic refuse (ashes)	41.4	53.8

Table 2. Comparison of Waste-Producing Areas in Average Typical Cities in Taiwan

Area / Content	Residential	Residential Commercial	Commercial
Vegetable	17.1	9.7	17.2
Wheat products	0.6	0.3	0.8
Fruits	0.8	3.9	1.5
Food scraps	18.5	13.9	19.5
Paper	7.5	7.6	13.4
Glass	2.8	2.9	3.8
Metal	1.1	2.3	1.1
Wood	0.4	1.0	0.8
Pottery	0.8	0.1	1.8
Grass, Leaves	6.1	2.9	9.8
Rubber	-	1.9	-
Leather	-	1.0	0.5
Plastic	2.3	3.2	2.4
Textiles	3.7	3.2	2.5
Sand, Ashes	56.8	60.6	44.1
Non-combustible material	60.9	65.4	51.1
Combustible material	39.1	34.6	48.9

in organic matter on a slope of 25-35 per cent. The city's downtown district and a large portion of its residential area lies to the east and north. The finished sanitary landfill area proposed would be used as a park.

In order to reduce the potential of water pollution and gas hazards special precautionary measures should be taken before site development.

COLLECTION OF SOLID WASTE

At present, refuse from each house is loaded into trucks which make street collections every 2 days. However, collection time is not always convenient for the housewife, especially during business hours. Besides, it is expensive, noisy and disrupts traffic.

In Taiwan, some people live by collecting still useful trash, such as paper, rags, bottles and cans. These persons might be hired as refuse collectors supplementary to the trucks. Their salary would be paid jointly by each household and the city government. These collectors would also sort and prepare the solid waste for recycling. The city sanitation trucks would then need only go the district collection stations to collect refuse.

After collection, the sanitation trucks would then go to a central collection station. This station would be built not too far from the city's downtown district and the planned site is near the open dump used at present. Thus, the trucks' collection routes will not be greatly changed.

One of the functions of the collection station would be to separate refuse into materials to be incinerated, composted or used as landfill.

The solid waste used as landfill would be transported to the landfill area by a narrow-gauge train. Such a type of train is used extensively in Taiwan to transport sugar cane from the fields to the factories. Wagons would be adapted to the specific need of carrying waste and Fig. 1 shows the landfill plan with the railway to transport waste from the collection station to the landfill.

IMPLEMENTATION OF THE PROPOSED SANITARY LANDFILL

Laboratory Investigation

A laboratory investigation must be made to determine the type and quantity of soils, ground water conditions, and the potential for gas and leachate problems at the site.

In order to research and provide the laboratory evaluation of experimental landfills and to form the basis for design and operation

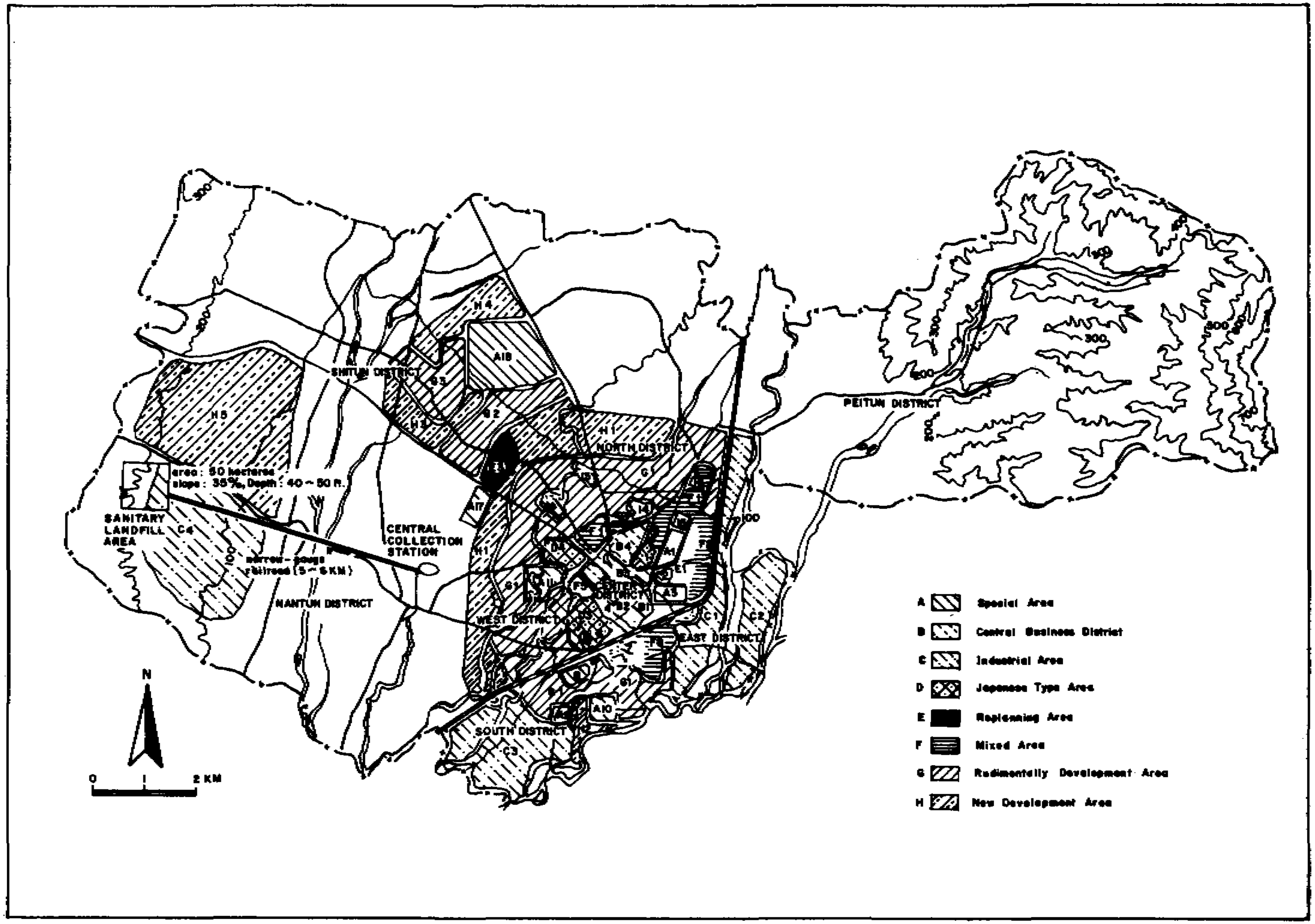

Fig. 1. Proposed Master Plan for Taichung Sanitary Landfill

of the sanitary landfill method as a controlled process, a laboratory model fermentation box has been developed to simulate the sanitary landfill

Samples are collected from different sources (such as domestic-type and industrial-type refuse) to fill the box. Under controlled conditions, the gas and leachate is analysed at intervals. Samples to be tested can be collected from the gas outlet, leachate outlet and the side pores.

Items to test include:

1. Types of percolating layer.

Several types of waste material (such as peat, slag or coke) are used as the percolating blanket, to see which type is the most satisfactory to prevent leachate.

2. Characteristics of leachate.

Leachate will be tested quantitatively and qualitatively, analysis being made for pH, hardness, BOD, COD, total alkalinity, dissolved solids, iron, sulphate, manganese, sodium, potassium, chloride, nitrate, and ammonia content.

3. Varying the depths of fill, such as varying the depths of refuse layer, varying the depths of soil layer and varying the quantities of rainfall.

4. Parametric consideration in landfill stabilisation, taking into account moisture content, temperature, pH and the recycling of leachate.

5. Gas analysis for CO_2, NH_3 and others.

6. Addition of microbial seed.

Site Development

The site development involves a considerable number of factors. Equipment includes roads, drainage and gas vent systems, gas hazard prevention equipment, disinfection equipment, insect control and a monitoring system. Operations involve site clearing and cleaning up, the construction of employee and maintenance facilities, the installation of a chain link fence around the perimeter of the site in addition to the daily unloading of refuse and rolling the surface.

Fig. 2 shows how, in ravines or valleys, the area-trench method is usually best.

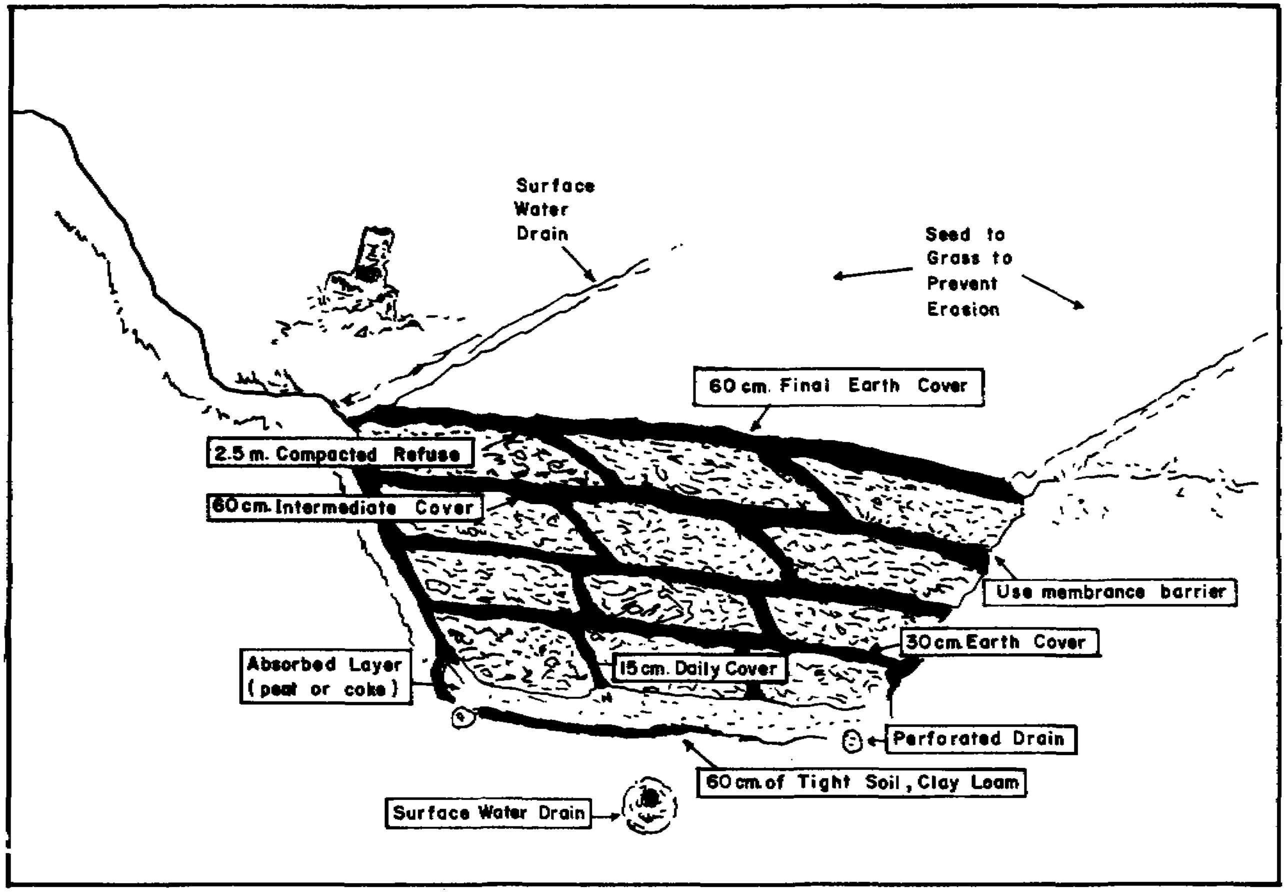

Fig. 2. In ravines or valleys, the area-trench method is usually best

Economic Assessment

The cost of the project may be separated into management, construction and operational cost. The Government estimate a cost of NT $ 13,000,000 (US $ 309,000) for sanitary landfill. It appears however, that a good deal more money must be spent to treat and properly dispose of wastes than to simply dump them.

In most of the low estimates usually given for sanitary landfilling, comparisons do not take into account the damage that has resulted, both in terms of human health and property losses. Leachate damage from one landfill site alone can cause thousands of dollars worth of damage and much inconvenience. So, why not spend more money on preventive work rather than save a lot of money initially - only to have to spend more in the future?

CONCLUSION

Solid wastes present a many-faceted problem. None of the options of one management method is satisfactory from all aspects. In developing nations, a shortage of available food and resources is associated with chronic pollution and disease caused by human and animal wastes. In developed nations, agro-industrial chemical pollution is now more serious than organic pollution.

As a developing country, the waste problem in Taiwan has not become as serious as in developed countries. The monitoring of the general environment is one aspect successfully curbing pollution. A federation of city, country, and district governments must co-operate to attack this problem.

It is important to contain and treat pollutants within a limited environment waste management park where engineered semi-natural ecosystems such as landfills do most of the work of decomposition and recycling. A planned urban development which preserves environmental quality and natural beauty and also provides ample room for recreation and reduction in pollution is very important for a developing country, and thus one should "design with nature", not against it.

OUTLINE OF DISPOSAL OF SOLID WASTE IN TAIWAN

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INTRODUCTION

The inadequate handling of solid waste inevitably causes pollution of water, air and soil. Thus it is an important subject in areas of environmental sanitation. In the past, refuse and nightsoil was the main source of solid waste. However, in view of the momentum in the degradation of the environment in Taiwan today, attributable to rapid industrial and economic development, industrial solid waste disposal will be a main concern in the future.

REFUSE DISPOSAL

Both the quality and quantity of refuse have undergone a persistent change. Quality in the past denoted dust and sand, all non-combustable substances, whereas refuse today comprises combustable substances such as plastic, and paper waste whose proportion is still on the rise. As for quantity, the amount of solid waste has a tendency to increase gradually with the improvement of living standards, especially in big cities where the average production today registers between 0.5 to 0.6 kg a day per capita. Outdoor refuse boxes were originally used to dispose of solid wastes, consequently adding to sanitary problems. But the situation has improved with the near completion of the "domestic trash container" project launched in 1963 by public health organisations. The important task of the future will be the classification of refuse for effective disposal, especially in metropolitan areas where incineration is required because of the shortage of land available for landfill. The storage of refuse under a classification system would be a definite future step.

In regard to refuse collection, the scheduled collection and transportation of refuse by packer type trucks on set routes has replaced manual collection and transportation by hand trailers or uncovered refuse cars via transfer stations. Currently, the government is responsible for 75 per cent of refuse collection and transportation while farmers take care of the rest.

Although main streets in the cities are entitled to mechanical collection, alleys and lanes are not. Therefore, the mechanisation of refuse collection remains an essential future quest. As for refuse disposal, the proportion of the traditional method of open dumping on empty lots and pit privies has decreased to 29 per cent, yielding to disposal by landfill (50.9 per cent among which Taipei accounts for 31.1 per cent alone) and composting disposal (10.3 per cent). Composting has been used for years in rural Taiwan. During the past decade or so, the provincial government has erected 20 semi-mechanical refuse composting treatment plants which were designed to handle a total of 1,399 tonnes of garbage daily. However, the actual amount settles around 260 tonnes due to mechanical failure or the difficulty in selling soil-conditioners. Two privately-owned composting plants have closed down for this reason.

Land reclamation along the seashore with refuse has been carried out in Keelung for years. But the resultant serious pollution of seawater has forced authorities to turn to landfill under the guidance of the Provincial Institute of Environmental Sanitation. In conclusion, incineration would be the ideal form of urban refuse disposal in face of the lack of lots available for landfill purposes.

NIGHTSOIL TREATMENT

Flush toilets with septic tanks are used by no more than 20 per cent of Taiwan's entire population. The remaining 12 million people use pit privies. It is estimated that 18,000 tonnes of nightsoil altogether, of 1.2 litres per capita, are produced daily. Governmental cleansing agencies collect 5,000 tonnes daily. Inevitably, the encouragement of the installation of flush toilets in the future will be the most important job in the field of nightsoil treatment. As for nightsoil collection and transportation, full mechanisation can be envisaged considering that a certain number of vacuum nightsoil collection trucks have replaced manual transferral, hand trailers and regular trucks in urban districts. Still, manual effort is needed in alleys and lanes of some cities. The ultimate goal will be the full mechanisation of nightsoil collection.

In terms of nightsoil treatment, the production of soil-conditioners that suited the fertilizer-depleted old days is gradually being given up on account of the mass production of chemical fertilizers as well as due to efforts to prevent the spread of gastro-communicable disease, parasitism and water pollution. Governmental health agencies have built nightsoil treatment plants in Fengshan, Pingtung, Chiching, and Keelung in addition to a nightsoil maturation tank in Kaohsiung. Taiwan's future objective is to release only nightsoil that has been treated and in this light, the establishment of nightsoil plants will be paramount. The plants will be capable of not only treating nightsoil, but also sludge from sewage treatment plants or septic tanks.

INDUSTRIAL SOLID WASTE DISPOSAL

Cinders, sludge, oil, acid base wastes, plastics, other chemical substances from the industries, or matter regarded as waste by government officials are the so-called industrial wastes termed in the current Solid Waste Disposal Act of Taiwan.

All industries prone to produce industrial waste should either act voluntarily or commission privately-owned cleansing agencies to discard their refuse, be it the intermediate or final waste. Disposal, whether by sanitary landfill, sea-dumping, resource recovery or reuse should be conducted according to the present Solid Waste Disposal Act, Air Pollution Control Act and Water Pollution Control Act to eliminate the contamination of disposal grounds, atmosphere and surroundings.

A careful survey on and analysis of natural conditions such as the meteorological, topographical streams, etc., water supply, land utilisation and urban construction of and around each sanitary landfill site is required. So is the sorting, the registration of the quantity of the solid waste and the maintenance of disposal facilities.

Besides organic components, industrial waste also contains inorganic yet harmful substances such as mercury, mercurial compounds, lead and lead compounds, cadmium, cadmium compounds, organic phosphate compounds, chromium compounds with 6 valencies, arsenic, arsenic compounds, HCN, cyanide, PCB (poly-chloro-biphenyl) and organic fluoride compounds. Toxic substances usually exist in cinders, metal shreds, sludge, dust, and acidic or alkaline waste products. Water contamination is apt to occur if treatment is not carried out before waste discharge.

Effective handling of industrial waste by government agencies is as follows:

- By monitoring and controlling final treatment;
- By extending technical assistance to final treatment;
- By effectively controlling secondary pollution arising from the final treatment; and
- By setting up and maintaining burial yards for wastes produced by small or medium enterprises which have encountered difficulties in obtaining individual or joint burial yards.

Despite the absence of reliable statistics on the discharge of industrial wastes by local enterprises, one can still discern that industrial waste production increases much faster then domestic waste (refuse, nightsoil) in Taiwan. However, resource recovery, the reuse of waste and the reduction of waste volume (by incineration) is urgently called for in Taiwan where land is scarce.

In 1977, raw materials containing barium carbonate purchased by a TV radio tube manufacturer in Taoyuan, northern Taiwan, was damaged during shipping. The National Health Administration (NHA) was called on to dispose the damaged barium carbonate consignment. After a thorough study, the burial method with solidifying by cement was recommended for areas unlikely to accommodate environmental pollution.

In another case, a plastic monomer factory in southern Taiwan submitted a daily sea-dumping disposal plan to the NHA concerning acidic liquid waste (containing 30 per cent H_2SO_4, 30 per cent $(NH_4)_2SO_4$ and a small amount of MAA etc.). Fearing the destruction of marine life and eutrophication resulting from a low pH and high nutrient, the NHA withheld its approval. Instead, we suggested the factory recover the H_2SO_4 or $(NH_4)_2SO_4$.

The amount of industrial waste handled has risen greatly along with the thrust of the industry and economy. For instance, the daily industrial waste output in Kaohsiung everyday has surged two-fold since 1975 and is expected to exceed the daily production of domestic refuse by 1.33 times in 1980 and 1.88 times in 1985. In view of detrimental pollution, the adequate handling of industrial waste in the future will be an essential task. An economical as well as valid solution has been contrived by the investigatory team of the Anti-pollution Pilot Project in the Kaohsiung area. Researchers recommended that all non-combustible solid matter, building material wastes, metal shreds, shattered glass, ceramics and cinders should be buried after treatment; non-combustible liquids such as acidic and alkaline wastes, sludge and dust should also be buried after neutralisation or consolidation; combustible refuse should be incinerated; and post-incineration biological residues, capable of causing secondary pollution, or excretions of poultry and livestock, must be decomposed into soil conditioner; finally, plastic and rubber wastes should be buried after grinding.

Presently, many rivers in southern Taiwan have been contaminated by wastes discarded by pig or poultry farms. Local health administrations are asked to supervise improvements. Persistent violators should be punished according to the Solid Waste Disposal Act, the NHA has ordered.

PLANNING OF OVERALL DISPOSAL FOR MUNICIPAL REFUSE AND INDUSTRIAL SOLID WASTE IN KAOHSIUNG

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INTRODUCTION

The promotion and development of industry has also brought about pollution of the air, rivers, the sea and soil, etc., which directly or indirectly has a serious effect on human life. Governments of such industrial countries have been doing their best to preserve the environment and remarkable results have been achieved in the field of air, river and sea pollution control.

However, as far as industrial solid waste is concerned, a suitable treatment and disposal system has not been established yet and there remain many problems to be solved. For example, in some areas landfilling prevails, which is subject to secondary pollution. This study of the industrial solid waste disposal system in Kaohsiung Area has been carried out by Working Group of the Pilot Project for Environmental Pollution Control in Kaohsiung Area, Taiwan, which was established in September 1975 in order to improve the industrial pollution in this area. This paper introduces an outline of result of the study.

SURVEY OF WASTE DISCHARGE IN THE KAOHSIUNG AREA

Total Quantity of Waste

The quantity of waste currently discharged in the Kaohsiung area is estimated to be 413,646 tonnes a month.

Table 1 shows amounts and types of waste classified by industry.

Enumerating them in quantitative order, they are manufacturing, followed by stock farming and hunting, mining, construction and the civil engineering industry.

The quantity of waste from manufacturing industry comprises 27.6 per cent of the total industrial waste output.

Table 1. - Industrial Waste Quantity in the Kaohsiung Area, Classified by Industry and Type of Waste (1975)

(Unit : Tonne/Month)

Type of Business			Primary Industry			Secondary Industry				Tertiary Industry							Life Environment Facilities	
Sorts of Waste			Agriculture	Stock Farming and Hunting	Forestry and Fishery	Mining	Construction	Civil Engineering	Manufacturing	Electric, Gas, Water Services	Wholesalers and Retailers	Financing Insurance and Real Estate	Transportation and Communication	School	Hospitals	Accommodation Services	Nightsoil and Sewage Treatment	Total
Combustibles	Non-polluting Waste	Waste Paper	0	0	0	0	0	0	747	10	1,317	160	112	0	0	0	0	2,346
		Chip Dust					64		14,658	50	182	293	537					15,784
		Waste Textile					0		201	0	35	0	3					239
		Others (Miscellaneous Refuse)				2	5		0	19	1,214	180	398	571	126	1,013		3,528
		Sub Total	0	0	0	2	69	0	15,606	79	2,748	633	1,050	571	126	1,013	0	21,897
	Waste Having a Possibility of Secondary Pollution when Incinerated	Waste Oil	0	0	0	2	0	0	2,084	2	196	0	2,628	0	0	0	0	4,912
		Waste Plastic				0			485	1	161		15					662
		Waste Rubber							47	0	1		0					48
		Animal and Vegetable Solid Refuse							7,578		7,058	23	8					14,667
		Others (Domestic Animal Excretion)		105,739					0		0	0	0					105,739
		Sub Total	0	105,739	0	2	0	0	10,194	3	7,416	23	2,651	0	0	0	0	126,028
		Total	0	105,739	0	4	69	0	25,800	82	10,164	656	3,701	571	126	1,013	0	147,925
Non-combustibles	Muddy and Liquid Waste	Waste Acid	0	0	0	0	0	0	3	0	19	0	0	0	0	0	0	22
		Waste Alkali							132		53							185
		Treatment Sludge				17,864			26,619	3,079	140		481				898	49,081
		Collected Dust				112			2,182	284			0				0	0
		Others				0			0	0								0
		Sub Total	0	0	0	17,976	0	0	28,936	3,363	212	0	481	0	0	0	898	51,866
	Solid Waste	Waste Metal	0	0	0	14	0	0	2,138	28	186	0	693	0	0	0	0	3,059
		Refuse Glass and Pottery				0			61	24	55		6					146
		Waste Building Materials				1,405	60,347	31,097	1,269	567	52		38					94,775
		Cinders				0	0	0	50,973	0	1		64					51,038
		Slag				59,730			4,450		0		172					64,352
		Others (Casting Sand)				0			485				0					485
		Sub Total	0	0	0	61,149	60,347	31,097	59,376	619	294	0	973	0	0	0	0	213,855
		Total	0	0	0	79,125	60,347	31,097	88,312	3,982	506	0	1,454	0	0	0	898	265,721
Grand Total			0	105,739	0	79,129	60,416	31,097	114,112	4,064	10,670	656	5,155	571	126	1,013	898	413,646

Furthermore, waste quantity classified by industry is shown by circular chart (Fig. 1) and Fig. 2 shows the quantity of waste classified by type and industry.

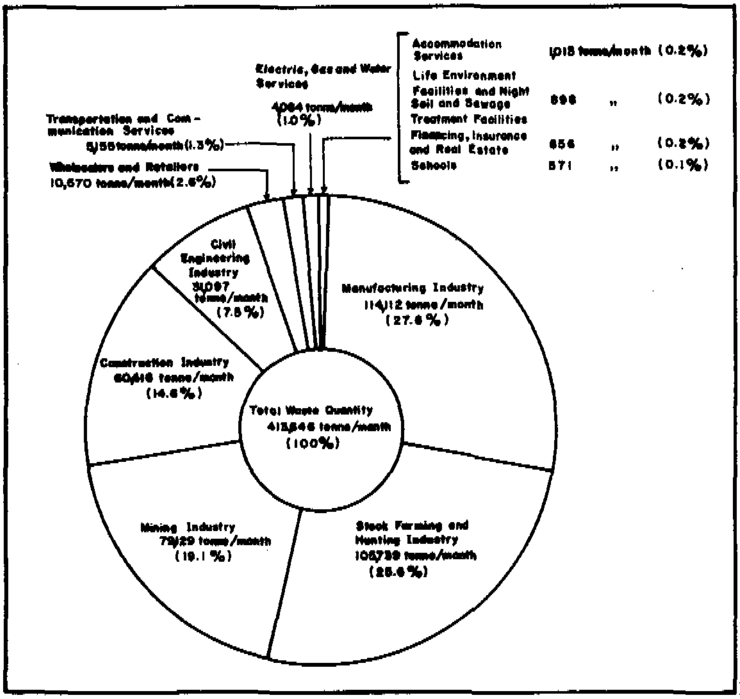

Fig. 1 - Waste Quantity in the Kaohsiung Area Classified by Industry

Waste from the Manufacturing Industry

A survey of the waste discharge from the manufacturing industry which comprises 27.6 percent of the total industrial waste output classified by type of industry is shown in Table 2 and Figs. 3 and 4.

The total quantity of waste from the manufacturing industry is 114,112 tonnes a month and enumerating it in quantitative order classified by industry, it is pottery, earthenware and stone products; wooden products and furniture manufacture and repair; food and beverages; iron, steel and nonferrous metals; followed by rubber, oil, coal and chemicals.

Pottery, earthenware and stone product manufacture, as clearly seen in Fig. 3, contributes 47.9 per cent which means that it comprises nearly half of the total waste discharged by manufacturing industry. Cinders (coke) is enumerated as a main waste.

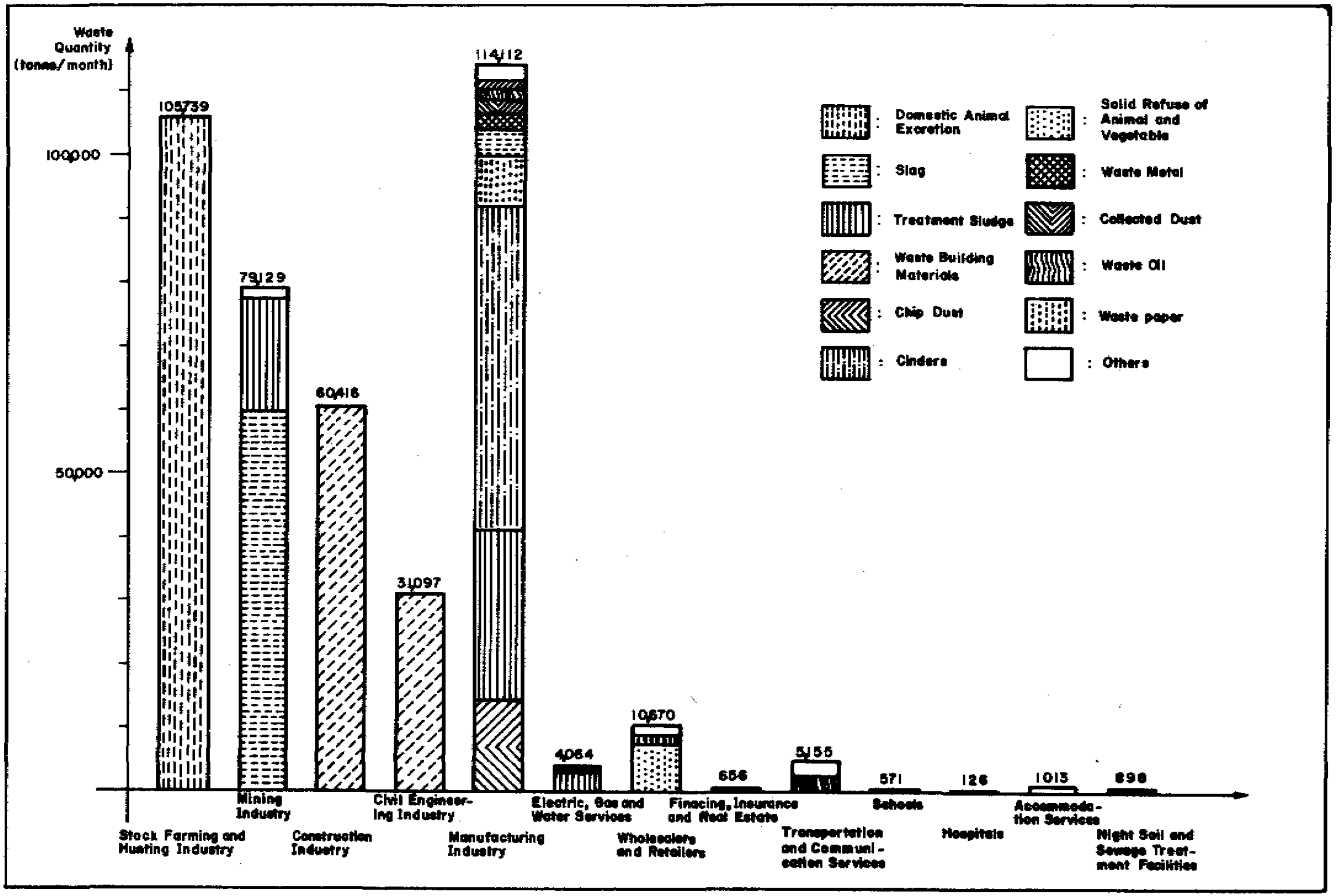

Fig. 2. Waste Quantity in the Kaohsiung Area Classified by Type and Industry

Table 2 - Industrial Waste Quantity in Kaohsiung Area, Classified by Type of Manufacture and Sorts of Waste (1975)

(Unit : Tonne/Month)

			Food and Beverage Manufacture	Textiles Leather	Wooden Products and Furniture Manufacture and Repair	Paper Manufacturing, Publishing and Printing	Rubber, Oil, Coal and Chemicals	Pottery, Earthenware and Stone Products Manufacture	Iron, Steel and Nonferrous Metal Manufacture	Metal Products and Machinery and In-Sturment Manufacture and Repair	Other Manufacturing Industries	Total
Combustibles	Non-polluting Waste	Waste Paper	32	2		192	447			74		747
		Chip Dust			14,658							14,658
		Waste Textile	7	147			46			1		201
		Others										0
		Sub Total	39	149	14,658	192	493	0	0	75	0	15,606
	Waste Having a Possibility of Secondary Pollution when Incinerated	Waste Oil					2,083			1		2,084
		Waste Plastic	2		41	215	88			139		485
		Waste Rubber								47		47
		Animal and Vegetable Solid Refuse	6,305	995			278					7,578
		Others										0
		Sub Total	6,307	995	41	215	2,449	0	0	187	0	10,194
	Total		6,346	1,114	14,699	407	2,942	0	0	262	0	25,800
Non-combustibles	Muddy and Liquid Waste	Waste Acid					3					3
		Waste Alkali					132					132
		Treatment Sludge	10,905	82	363	1,177	4,695	2,700	6,599	98		26,619
		Collected Dust			2,181					1		2,182
		Others										0
		Sub Total	10,905	82	2,544	1,177	4,830	2,700	6,599	99	0	28,936
	Solid Waste	Waste Metal					5		1,100	1,033		2,138
		Refuse Glass and Pottery	14					47				61
		Waste Building Materials				1		1,268				1,269
		Cinders			550			50,423				50,973
		Slag			12	327		198	3,856	57		4,450
		Others (Casting Sand)							424	61		485
		Sub Total	14	0	562	328	5	51,936	5,380	1,151	0	59,376
	Total		10,919	82	3,106	1,505	4,835	54,636	11,979	1,250	0	88,312
Grand Total			17,265	1,226	17,805	1,912	7,777	54,636	11,979	1,512	0	114,112

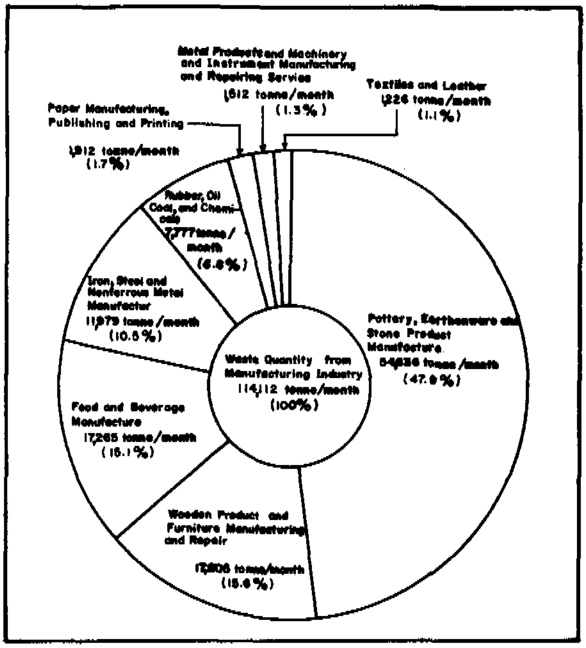

Fig. 3 - Waste Output from the Manufacturing Industry in the Kaohsiung Area.

Indeed the waste output from pottery, earthenware and stone product manufacturing industry is 54,636 tonnes a month which is equivalent to 13.2 per cent of the total industrial waste in the Kaohsiung Area.

Waste Quantity Classified by Type

Table 3, Figs. 5 and 6 present the total industrial waste output of 413,646 tonnes a month classified by type of waste.

Enumerating the wastes in these figures in quantitative order, they are: domestic animal excretion; waste building materials; slag; cinders and treatment sludge. The total quantity of these 5 sorts of waste amounts to 368,985 tonnes a month which is equivalent to 88.3 per cent of the total waste quantity.

Also, the main dischargers of these 5 sorts of waste are, respectively, the stock farming and hunting industry; the construction industry; the mining industry; the manufacturing industry and wholesale and retail.

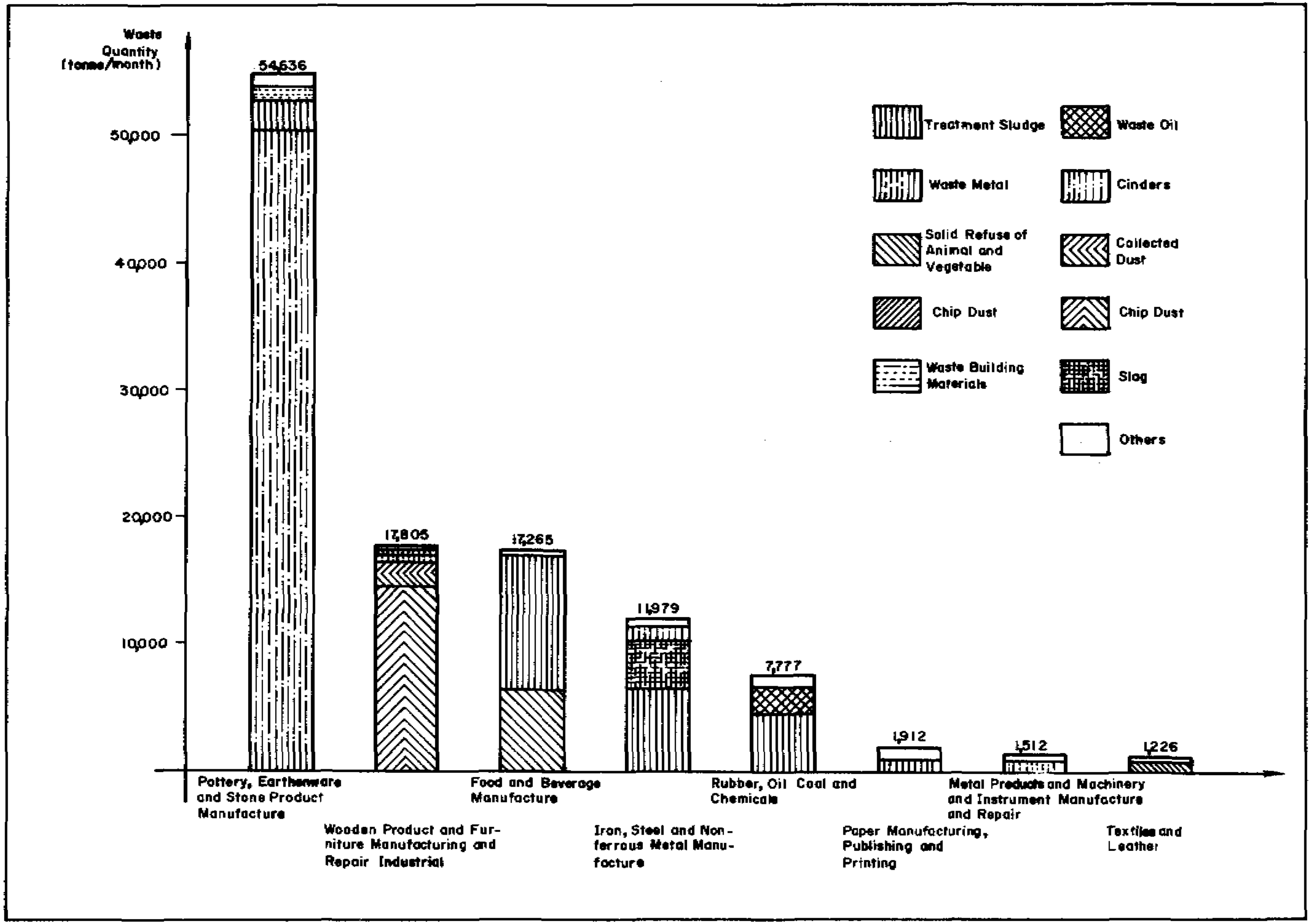

Fig. 4. Industrial Waste Output in the Kaohsiung Area, Classified by Manufacturer and Type of Waste

Table 3 - Waste Quantity Classified by Sorts of Waste (1975)

			Waste Quantity Tonne/month	Com-Position Ratio %	Classification of Industry Having Larger Waste Quantity: Name of Industry	Waste Quantity Tonne/month	A %
Combustibles	Non-polluting Waste	Waste Paper	2,346	0.6	Wholesaler and Retail	1,317	56.1
		Chip Dust	15,784	3.8	Manufacturing	14,658	92.9
		Waste Textile	239	0.1	Manufacturing	201	84.1
		Others (Miscellaneous Refuse)	3,528	0.9	Wholesaler and Retail	1,214	34.4
		Sub Total	21,897	5.3	Manufacturing	15,606	71.3
	Waste Having a Possibility of Secondary Pollution when Incinerated	Waste Oil	4,912	1.2	Transportation and Communication Service	2,628	53.5
		Waste Plastic	662	0.2	Manufacturing	485	73.3
		Waste Rubber	48	0.0	Manufacturing	47	97.9
		Animal and Vegetable Solid Refuse	14,667	3.5	Manufacturing	7,578	51.7
		Others (Domestic Animal Excretion)	105,739	25.6	Stock Farming and Hunting	105,739	100.0
		Sub Total	126,028	30.5	Stock Farming and Hunting	105,739	83.9
		Total	147,925	35.8	Stock Farming and Hunting	105,739	71.5
Non-combustibles	Muddy and Liquid Waste	Waste Acid	22	0.0	Wholesaler and Retail	19	86.4
		Waste Alkali	185	0.0	Manufacturing	132	71.4
		Treatment Sludge	49,081	11.9	Manufacturing	26,619	54.2
		Collected Dust	2,578	0.6	Manufacturing	2,182	84.6
		Others	0	0.0		0	0.0
		Sub Total	51,866	12.5	Manufacturing	28,936	55.8
	Solid Waste	Waste Metal	3,059	0.7	Manufacturing	2,138	69.9
		Refuse Glass and Pottery	146	0.0	Manufacturing	61	41.8
		Waste Building Materials	94,775	22.9	Construction	60,347	63.7
		Cinders	51,038	12.3	Manufacturing	50,973	99.9
		Slag	64,352	15.6	Mining	59,730	92.8
		Others (Casting Sand)	485	0.1	Manufacturing	485	100.0
		Sub Total	213,855	51.7	Mining	61,149	28.6
		Total	265,721	64.2	Manufacturing	88,312	33.2
		Grand Total	413,646	100.0	Manufacturing	114,112	27.6

Note: (A) is percentage to the waste quantity classified by sorts of waste.

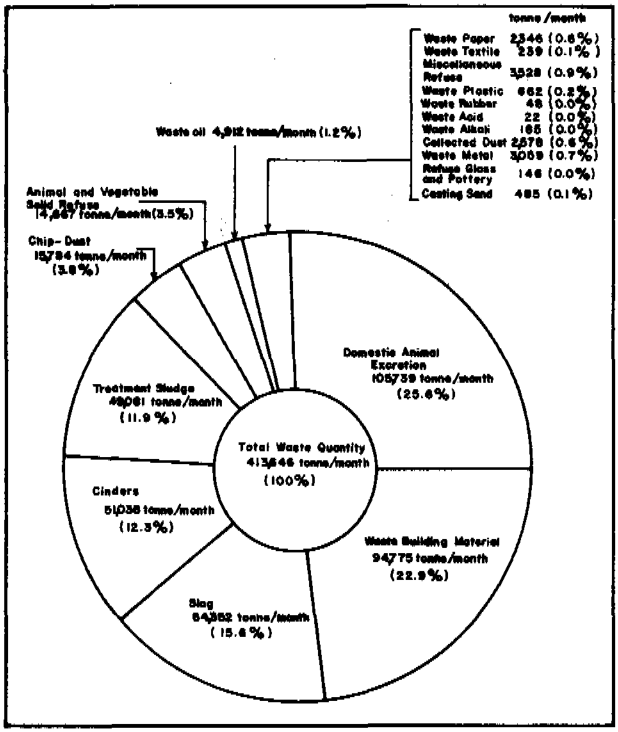

Fig. 5 - Waste Quantity Classified by Type of Waste

Waste Quantity Classified by Area

Kaohsiung city and vicinity is classified into 7 areas, the city area, followed by areas, A, B, C, D, E and F (See Fig. 7).

Waste output by area, in order, is Kaohsiung city, followed by Area C, Area A, Area D, Area B, Area E and Area F. The waste quantity discharged from Kaohsiung city area comprises 46.5 per cent of the total waste quantity for the whole area.

Also, waste output from 4 areas, namely Kaohsiung city area, Area C, Area A and Area D reaches 90.2 per cent of the total waste quantity for the whole area, and because of this, it can be said that the waste from Kaohsiung area is mostly discharged from these 4 areas.

Table 4 and Figs. 8 and 9 indicate waste output by area.

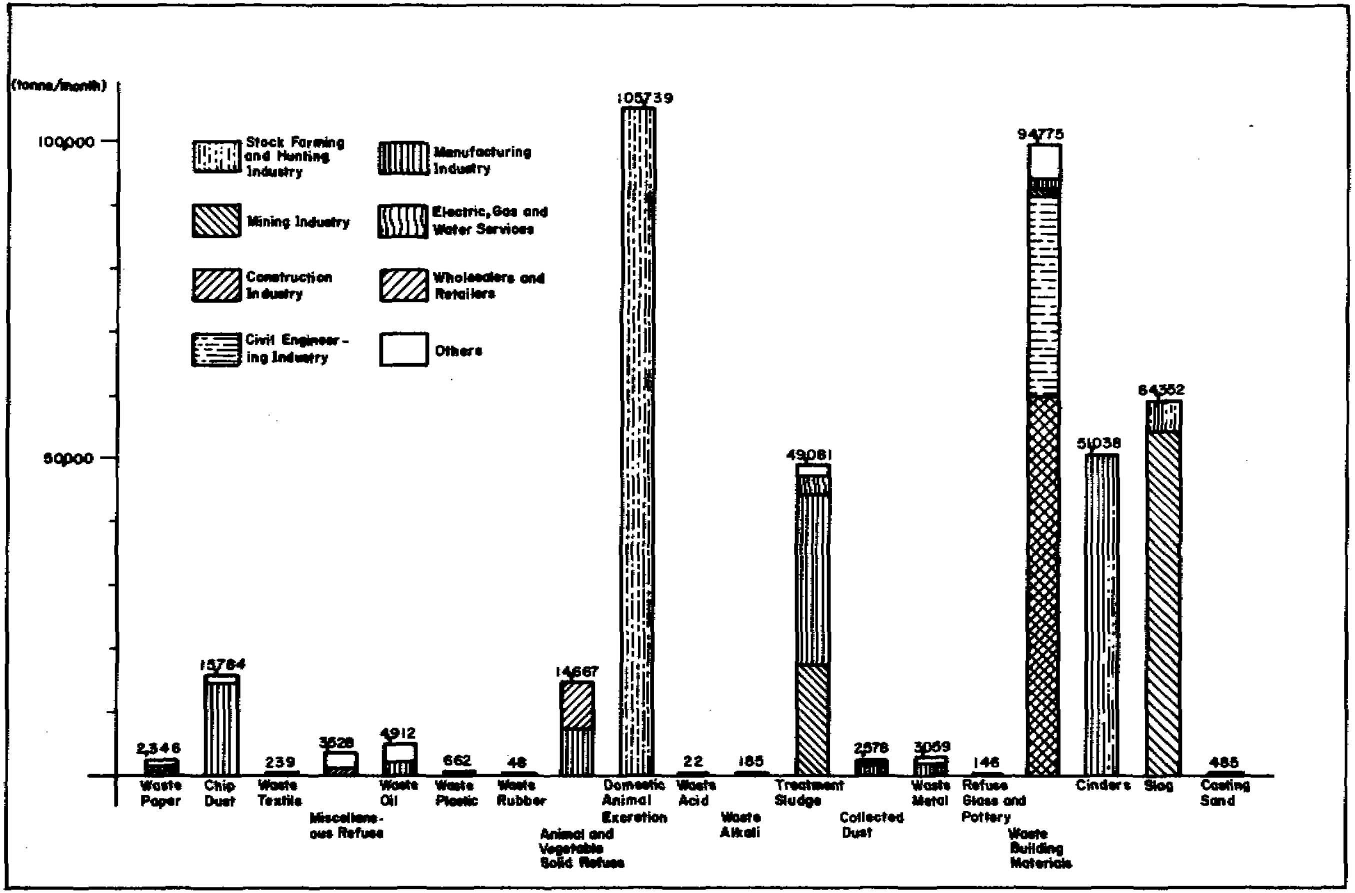

Fig. 6. Waste Quantity Classfied by Industry and Sorts of Waste

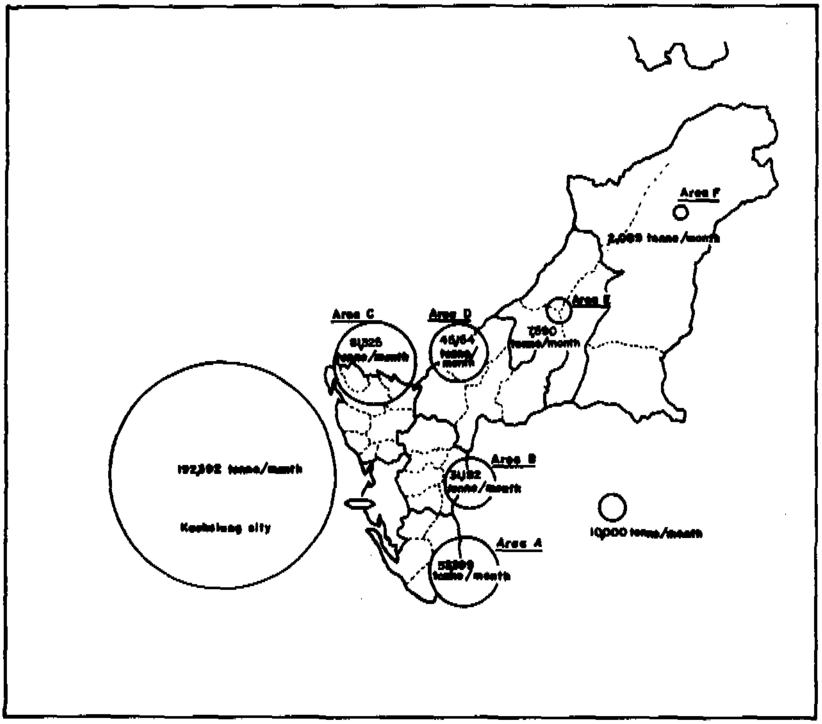

Fig. 7 - Waste Quantity in Kaohsiung Area Classified by Area

DRAFT PLAN FOR THE TREATMENT AND DISPOSAL OF INDUSTRIAL WASTES IN THE KAOHSIUNG AREA

In recent years the quantity of industrial wastes discharged due to economic and industrial development has increased remarkably and the problem has arisen that such wastes include materials harmful to mankind which are not biodegradable.

This treatment and disposal plan aims at establishing a safe and economical system for treatment and disposal of industrial wastes in the Kaohsiung area by:

- Clarifying responsibility for treatment and disposal.
- Clarifying treatment and disposal guides for industrial wastes classified by type of waste;
- Promotion of wide area treatment and disposal project planning in the Kaohsiung area.

Table 4 - Waste Quantity Classified by Area

		Waste Quantity Tonne/ Month	Ratio %	Main Wastes
Kaohsiung City		192,392	46.5	1. Waste building materials 2. Slag 3. Cinders
Kaohsiung	Area A	53,399	13.0	1. Waste building materials 2. Domestic animal excretion 3. Treatment sludge
	Area B	31,182	7.5	1. Domestic animal excretion 2. Slag 3. Cinders
	Area C	81,325	19.7	1. Domestic animal excretion 2. Slag 3. Treatment sludge
	Area D	45,154	11.0	1. Domestic animal excretion 2. Slag 3. Treatment sludge
	Area E	7,590	1.8	1. Miscellaneous refuse 2. Cinders 3. Treatment sludge
	Area F	2,089	0.5	1. Domestic animal excretion 2. Solid refuse of animal and vegetable 3. Miscellaneous refuse
		221,212	53.5	1. Domestic animal excretion 2. Slag 3. Waste building materials
Kaohsiung Area		413,646	100	1. Domestic animal excretion 2. Waste building materials 3. Slag

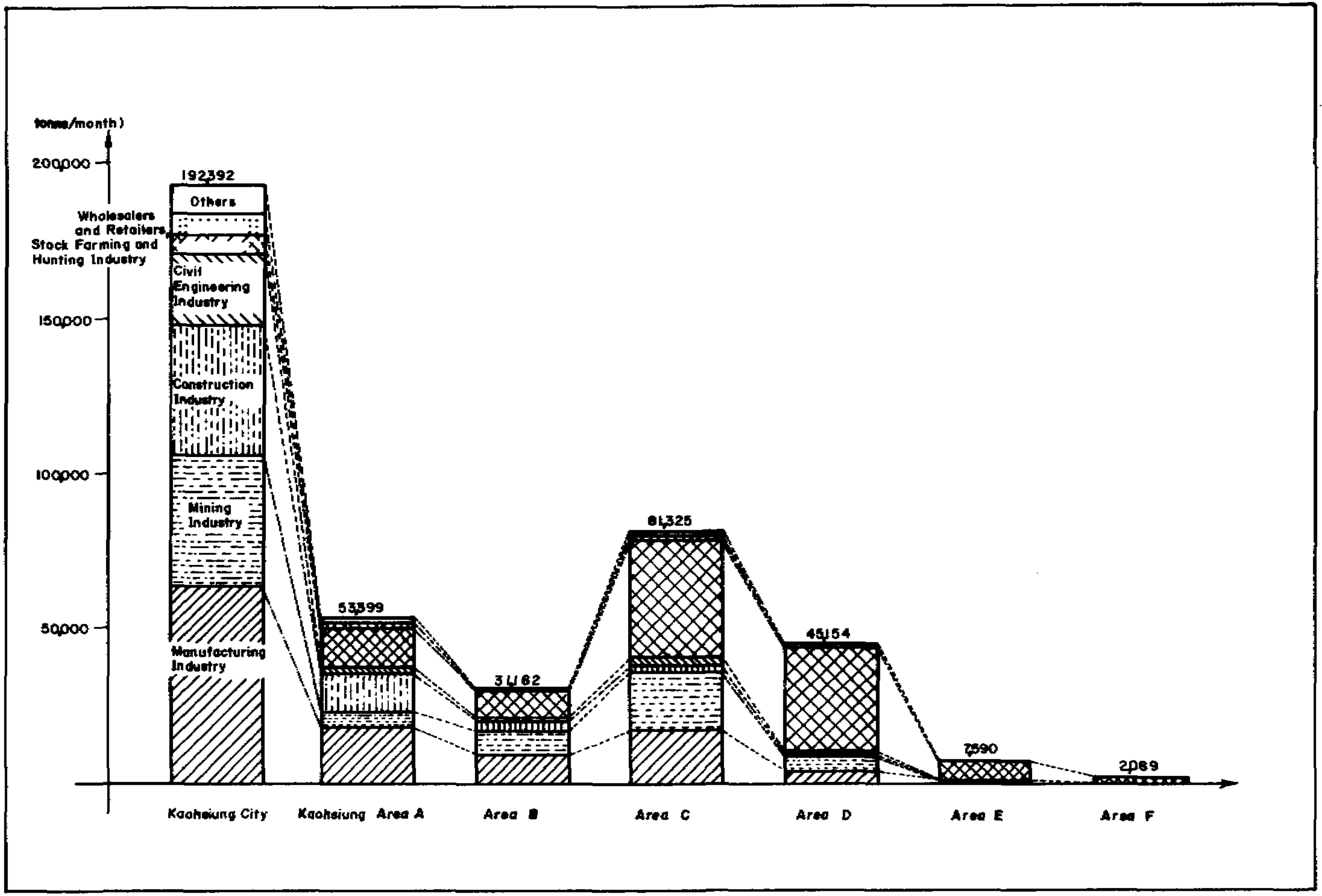

Fig. 8. Waste Quantity in Kaohsiung Area Classified by Area and Industry

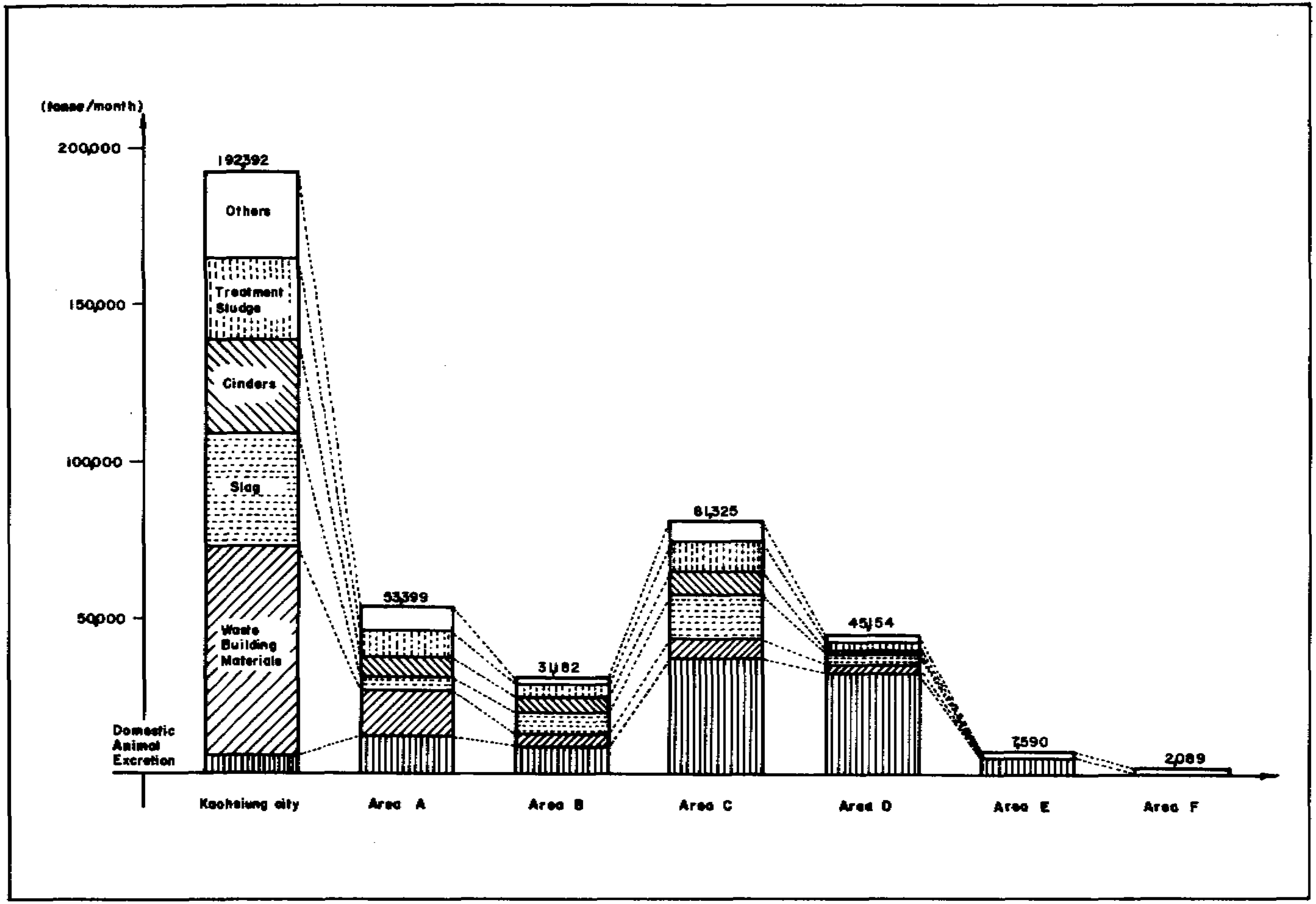

Fig. 9. Waste Quantity in Kaohsiung Area Classified by Area and Sorts of Waste

The planning principle is based on 4 factors:

(1) Polluters' responsibility	- Industrial wastes produced in business activities are to be the producers' responsibility for treatment.
(2) Recycling	- In treatment of industrial wastes, recycling and reuse should be attempted as much as possible.
(3) Pollution-free treatment	- In the treatment of industrial wastes, prevention of secondary pollution such as air, water and soil pollution as well as a reduction in quantity is to be achieved.
(4) Effective treatment	- Industrial wastes should be treated most economically and effectively after overall consideration of types of business, kind and nature of wastes, treatment technique, local conditions, etc.

The wastes produced in the business activities in the wide sense including activities for public interests as well as wastes from business activities for private interests are shown in Table 5.

Period of Planning

With 1976 as the first year, 1980 has been set as the interim target year and 1986 is the final target year, totalling 10 years for the entire plan.

Since treatment and disposal of industrial wastes are flexible regarding regulations, techniques and other respects, necessary adjustments and corrections are to be made in accordance with the changes of circumstances in the following:

- Change of discharge of industrial wastes due to fluctuations in industrial structures and economic growth;
- Development of techniques for the treatment of wastes;
- Development of treatment facilities by enterprises themselves and of commercialisation of business in waste treatment.

Guide to Treatment and Disposal of Wastes Classified by Type

Methods of treatment and disposal of industrial wastes change in accordance with social and technical development, and the methods herein applied are based upon the following classified by the year (Table 6) and area (Table 7).

Table 5 - Typical Industrial Wastes

Name of Wastes	Examples
Paper Waste	Cut chips, bookbinding wastes, printing wastes, etc.
Wood Chips	Sawdust, planed chips, wood chips, bark, etc.
Textile Wastes	Cotton, wool, silk, hemp, mixed yard, waste thread, waste cotton, waste cloth, etc.
Animal and Plant Leftovers	Bones, refuse, fats of birds, brute, fish, candy lees, brewed lees, beer lees, etc.
Rubber Wastes	Wasted tyres, etc.
Metal Wastes	Empty can, empty drum, cut chips, ground chips, etc.
Glass Wastes	Bottles, glass wastes, etc.
Ceramic Wastes	Ceramic wastes, firebrick wastes, etc.
Slag	Leftovers at blast, open-hearth, electric furnaces, slag, leftovers, etc. at cupola
Cinders	Coal cinders, ashes, dregs at furnace cleaning, etc.
Construction Wasted Materials	Concrete broken piece, brick broken piece, earth and sand, etc.
Animal Extrusion	Sewage at pig keeping yard, etc.
Collected Dust	Dust collected by electric dust collector, cyclon, etc.
Wasted Oil	Lubricant, insulation, machine, solvent oil, oil sludge, etc.
Wasted Acid	Sulphuric acid, hydrochloric acid, acetic acid, etc.
Wasted Alkali	Wasted soda liquid, etc.
Sludge	Alminoferric cake, surplus by the activated sludge method, digested sludge, etc.
Wasted Plastics	Plastic sheet, bag, styrofoam, etc.

Table 6 - Treatment and Disposal Guide to Wastes Classified by Type in the Kaohsiung Area

	Treatment and Disposal Guide	
	1976 ~ 1980	1981 ~ 1985
Paper Waste Wood Chips Textile Waste Miscellaneous	Effective utilisation as various kinds of fuel and materials is to be tried. What cannot be utilised is to be incinerated together with general waste, cinders and land reclaimed in Kaohsiung area. Other areas are to be directly land filled without primary treatment.	First of all, effective utilisation as various kinds of fuel and materials are to be tried. What cannot be utilised is to be incinerated together with general waste and cinders are to be reclaimed in Kaohsiung City, Kaohsiung Prefecture, Areas A, B and C. Other areas are to be directly land filled without primary treatment.
Waste Oil	First of all recycling is to be tried. What cannot be reutilised is to be collected and incinerated.	→ (Same as left)
Waste Plastics Rubber Wastes	First of all recycling is to be tried. What cannot be reutilised is to be crushed by producer in accordance with requirements and land filled.	→ (Same as left)
Solid Unnecessities Related with Animal and Plant	Are to be made into fertilizer and feed by producer and fertilizer and feed manufacturers.	→ (Same as left)
Animal Sewage	To be made into fertilizer (reduced to soil)	→ (Same as left)
Waste Acid Waste Alkali	First of all, collection for recycling is to be tried. What cannot be utilised is to be neutralisation treated after collection in wide area. (After execution of pH control in public water areas).	→ (Same as left)

(Table 6 Continued)

	Treatment and Disposal Guide	
	1976 ~ 1980	1981 ~ 1985
Sludges	After dehydration treatment by producers, they are to be land filled. In reclaiming organic sludges, measures for preventing secondary pollution due to reclamation are to be taken. Sludges containing polluting materials are to be land filled or discharged into the sea after pollution-free treatment by concrete solidising, etc. for preservation of environment.	→ (Same as left)
Collected Dust	Is to be land filled after treatment for preventing dispersion by packing etc. That which contains polluting materials is to be land filled or discharged into the sea after pollution-free treatment by concrete solidising, etc.	→ (Same as left)
Metal Chips	First of all recycling such as reutilisation, reclamation, etc. is to be tried. Where this cannot be achieved, the remainder is to be land filled after crushing treatment by producers in accordance with requirements. Slag containing polluting materials are to be land filled or discharged into the sea after pollution-free treatment such as concrete solidising, etc.	→ (Same as left)
Glass Chips		
Slag		
Construction Waste Materials	Are to be land filled after crushing treatment in accordance with requirements by producers. Cinders containing polluting materials are to be land filled or discharged into the sea after pollution-free treatment such as concrete solidising, etc.	→ (Same as left)
Ceramic Wastes		
Cinders		
Casting Sand		

Role Planning for Treatment and Disposal

Roles are set as follows so that producers' responsibility for treatment to whom main duties are concentrated may be realised and supplementary policies of state, prefecture and city governments who promote producers' execution of responsibility may be organised.

Producers should always have clear pictures of quantity and nature of wastes produced by their business activities, make out plans for treatment, and treat them responsibly in accordance with the standards set in the regulations. In treatment of wastes, producers should participate actively in wide area treatment and disposal project planning for cooperation in the effective installation of intermediate treatment facilities and the securing of final disposal space. Producers should also try to reduce quantity of waste and render it pollution-free by improving the manufacturing process and try to recycle, wherever possible. In processing and sales, etc., care should be taken that related products and containers are not turned into wastes.

Treaters (mainly forwarders) should treat waste in accordance with the standards set in regulations and during such treatment, should cooperate with both enterprises consigned and with the prefecture, city, etc.

The prefecture or city should plan treatment and disposal in accordance with the changing situation regarding treatment of industrial wastes. They should try to have a clear picture of the status of exhaust and treatment of industrial wastes guide, supervise and advise producers and treaters so that they may treat wastes properly and they should conduct research and try to collect information on the development of techniques for waste quantity reduction, recycling, treatment, disposal, etc. They should try to promote wide area treatment and disposal projects such as installation of primary treatment facilities and the securing of final disposal spaces, etc. and they should ask the government to prepare regulations for the proper treatment of industrial wastes, to promote development of techniques for treatment, disposal and materialsation of industrial wastes and to afford financial assistance and credit for the installation of primary treatment facilities and the securing of final disposal sites.

Wide Area Treatment and Disposal Projects

Wide area treatment and disposal projects are necessary because although it is quite clear that producers are responsible for the treatment of industrial wastes, this raises many questions. It is necessary to promote wide area treatment and disposal projects for the following reasons.

- Producers in the Kaohsiung area consist mainly of medium and small-sized enterprises and it is not effective to make each of them treat industrial waste from viewpoints of technique and economy.

- It is practically impossible for each producer to secure final disposal space.
- By wide area treatment, highly technical and overall treatment can be achieved.
- Thorough management, supervision and guidance is necessary to prevent secondary pollution.

The following systems for treatment and disposal should be considered and each has both its merits and demerits, and therefore in selecting one due consideration must to be taken among the persons involved. The systems are:

- The limited company system
- The direct operation system by prefecture, city, etc.
- The indirect operation system by prefecture, city, etc.
- The operation consignment system
- The third sector system

Planning for the installation of wide area treatment and disposal facilities is shown in Table 7.

Table 7 - Planning for Installation of Wide Area Treatment and Disposal Facilities

		Kaohsiung	Kaohsiung Prefecture					
			Area A	Area B	Area C	Area D	Area E	Area F
Wide Area Treatment Disposal Facilities Installation Planning	1976 – 1980	(1) Dust Incinerator (2) Wasted Oil Incinerator (3) Final Disposal Facilities *(Wasted Acid, Wasted Alkali Overall Neutralisation treatment Facilities) **(Concrete Solidising Facilities)	(1) Wasted Oil Incinerator (2) Final Disposal Facilities *(Wasted Acid, Wasted Alkali Overall Neutralisation treatment Facilities) **(Concrete Solidising Facilities)	Final Disposal Facilities	(1) Wasted Oil Incinerator (2) Final Disposal Facilities	(1) Wasted Oil Incinerator (2) Final Disposal Facilities	Final Disposal Facilities	Final Disposal Facilities
	1980 – 1985		Dust Incinerator		Dust Incinerator			

* To be installed as soon as possible, after draft water pH control is effected, actual exhaust research and investigation on capacity of facilities.

** To be installed as soon as possible, after noxious material control is effected, research on waste quantity including noxious materials and investigation into the capacity of facilities.

SANITARY LANDFILL AT ONN NUJ DUMPING GROUND

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INTRODUCTION

The refuse yield from Bangkok's 4.8 million population is approximately 2,950 tonnes a day (11,800 metres^3). However, the collecting capability averages 1,400 tonnes a day. Disposal is mostly done by open dumping, especially at the Onn Nuj Disposal Ground, where there are about 230 acres of available land. The refuse piled up now occupies about 50 acres with of 2.3 million metres^3 left and 2,200 metres^3 of raw refuse is being added daily. The side effects from disposal by open dumping are very dangerous, and Bangkok's Bureau of Sanitation realises the problems and has an important plan to introduce sanitary landfill at the Onn Nuj open dumping ground.

OBJECTIVES

In order to relieve the potential health hazard and public nuisance created by the open dumping of refuse at the Onn Nuj Ground, efforts will be made to take the piled-up open-dumped refuse and redispose of it by sanitary landfill; to stop the open dumping of raw refuse and use the sanitary landfill technique whenever the amount of refuse at the Onn Nuj Ground exceeds the capacity of compost plants at Onn Nuj (capacity 640 tonnes a day). When the compost plant at Onn Nuj is operating, the composted refuse must be disposed of by sanitary landfill.

The procurement of equipment and facilities must be finished within 2 years and the time for the project to be completed is 5 years.

EXECUTION

Run-off waste from the open dump has flooded most of the proposed area for the sanitary landfill project. Suitable waste water treatment should be considered before it spills over outside the limits of the open dump ground.

The operational technique used will be the trench area ramp method, with a trench depth of 3 - 4 metres, 1 metre being a ramp from the actual ground level. The compost and soil cover is 0.75 metres, and the trench beds theoretically dry.

The equipment required includes draglines and excavators for digging the trenches, dump trucks for earth haulage, tractors for moving the open-dumped refuse to the prepared trenches and to compact each layer, and sewage pumps for dewatering purposes.

The old open-dumped refuse would be moved and lowered down into the prepared trenches by tractors which would also carry out the compacting. Water would be sprayed on the refuse pile to diminish dust and smoke. At the end of each day's operation there is no need for a covering of soil if the prepared trench is not yet filled up with the old refuse.

Raw refuse collected daily by truck must be dumped in the prepared trenches, with layers compacted to a thickness of 1.00 to 1.50 metres until the layers reach to proposed level. The prepared soil would then be used to cover and compact the refuse. At the end of each day's operation, should the trench not be filled up, soil should be spread out over the exposed refuse in the trench and compacted to give a 0.20 metre cover. The following day when operations begin the raw refuse is dumped on that cover until the trench is filled.

The schedule for procurement is shown in Table 1.

Table 1. Procurement Schedule

Item	First Year	Second Year
Tractor	2	2
Dragline	1	1
Excavator	1	1
Front Loader	1	0
Dumptruck	10	10
Sewage Pump	3	2
Pick-up truck	2	0

PROBLEMS

Most of proposed sites are low-lying and the soil is usually soft clay, with a high water content and requiring dewatering. The preparation of soil for covering the refuse may thus be difficult because the damp, soft clay may need many days for drying.

To treat waste water, an aerated lagoon is planned in the short term, while in the long run an extended aeration process will be in operation.

Background material prepared by the Environmental Resources Limited, U.K. suggests water treatment should be a combination of biological and physico-chemical treatment. However, laboratory tests using alum as a coagulant did not yield satisfactory results.

CURRENT REFUSE DISPOSAL METHODS IN BANGKOK

Bangkok has 2 major open dumping grounds at Onn Nuj and Nongkham, Onn Nuj being the more important. They present tremendous problems, particularly the run-off waste water onto the private property, most important from the public health point of view and dangerous as by now most of open-dump grounds are surrounded by settlements.

Bangkok has a total of 4 compost plants planned with a total capacity of 1,120 tonnes a day and the first plant began operations early last year. Located at Nongkham, its capacity is 160 tonnes a day and produces 75 tonnes of composted refuse a day.

The second plant will be at Ramintha in northern Bangkok which capacity of 320 tonnes a day and will have an output 180 tonnes a day of composted refuse.

It expected that other 2 compost plants will be in operation soon. If all the compost plants have a combined capacity of 1,120 tonnes a day, then from a total collection of 1,400 tonnes a day. There should be 280 tonnes a day of raw refuse left for disposal at the open dump.

The Bureau of Sanitation in Bangkok is also considering conducting a feasibility study for what would be Bangkok's first incinerator plant. Ideally, its capacity would be between 300 and 600 tonnes a day.

Electricity is not expected to be a by-product as the refuse has a low calorific value. Smoke pollution control is not to be emphasised while there will be no excessive use of sophisticated devices. The Bureau would like to have the final design within 2 years.

The Bureau of Sanitation would like to implement the project by setting up the staff for preparing a term of references, have a consultant engineer make a feasibility study and prepare the final design for the proposed incinerator. The bureau would provide the budget and the staff to work with the consultant engineers.

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