WASTE advisers on urban environment and development

Workshop on sustainable municipal waste water treatment systems

12-14 November 1996
Leusden, the Netherlands

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ETC in cooperation with WASTE

Edited by:
Annelies Balkema
Herbert Aalbers
Enno Heijndermans

ETC Netherlands

LIBRARY IRC
Pox 93190, 2509 AD THE HAGUE
Tel.: +31 70 30 689 80
Fax: +31 70 35 899 64
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Summary

From November 12 to 14, 1996 ETC-Netherlands in cooperation with WASTE conducted the "Workshop on Sustainable Municipal Waste Water Treatment Systems" in Leusden. The workshop brought together 35 experts in the field of waste water treatment from 17 different countries. The main objective of the workshop was to identify existing constraints for the wider implementation of more sustainable waste water treatment systems globally, and to identify ways to overcome these constraints.

A problem analysis resulted in an overview of the existing constraints:

- no interest in changing to new waste water treatment technologies due to a vested interest in conventional systems,
- reluctancy to change to alternative systems, based on :
    - lack of awareness due to lack of information and lack of promotion,
    - lack of pressure from interest groups,
    - lack of institutional support.

Approaches to overcome the identified constraints are:

- collection and dissemination of general information on more sustainable waste water treatment systems;
- collection of factual data on operating more sustainable waste water treatment systems, including technical, financial and social/economic data (a first step for this will be standardisation of information to be collected);
- increased discussion and exchange of information and experience among people implementing these systems and those interested in applying the technologies developed.

Selected follow-up projects that are therefore proposed:

- setting up an expert network using e-mail,
- a world wide demonstration project,
- writing a book on alternative waste water treatment systems,
- providing training courses,
- and making video documentaries.

Furthermore participants in the workshop expressed strong interest in continuing cooperation in the field of sustainable waste water treatment.

Foreword by director ETC-Netherlands

The Workshop on Sustainable Municipal Waste Water Treatment was organised and conducted by ETC-Netherlands, Leusden, in cooperation with WASTE, Gouda, and with financial contributions from ECOOPERATION, DGIS, WASTE, and ETC. Thanks to all participants the workshop was a success.

ETC was established in 1974 as a non-profit organisation based in the Netherlands. The original aim was to assist developing countries in the fields of training and organisational development. The name ETC, Educational Training Consultants, still reflects that old spirit. In the years since 1974, ETC has grown into an international group with offices in the Netherlands, India, Sri Lanka, Kenya, Zimbabwe, Andes, and the United Kingdom. At the moment, ETC employs about 240 people, the majority of which are project staff.

ETC's main objective is to encourage and support local initiatives which aim to build sustainable development. People centred, ecologically sound and building on local expertise have always been the key concepts defining the ETC-approach. Areas of attention are agriculture, forestry, energy, water, and institutional and capacity development.

The reason ETC organised this workshop is the concern about the decreasing availability of fresh and clean water for consumption, household use, agriculture, and other uses. In order to secure the availability of clean water new, innovative, and more sustainable approaches are needed.

Based on our concept of people centred approaches we are convinced that the choice of the most sustainable system is very site specific and will depend on the local conditions. We need to listen to the people concerned and build on local expertise when helping to select the most appropriate, most sustainable solution for waste water treatment. We recognise that we can only provide assistance in a process that is carried out by the people directly concerned. Our help is therefore limited to providing input that these people cannot provide themselves. The workshop was meant to identify and analyse the appropriate input with all participants and to prepare a plan of action.

The workshop included a number of papers on more sustainable systems which were only meant to provide examples. Limited time was made available to discuss the definition of sustainability of waste water treatment systems as this was not an objective for this workshop. Furthermore it was not the intention to cover the whole range of more sustainable waste water treatment technologies. The main point of attention was the slow dissemination of these technologies in general. The workshop was meant to identify the reasons behind the slow dissemination in order to overcome these constraints.

ETC's effort in this field will not stop at the end of the workshop or with the publishing of the proceedings. We have committed ourselves to the implementation of the recommended follow-up to this workshop. However, We do not intend to do this alone. We would like to do this with the people involved in this workshop and with other interested people.

Another kind of follow-up lies in the hands of the participants from Costa Rica. ECOOPERATIONS made the financial contribution to this workshop because of its relevance for the Models of Regional Sustainable Development (MRSD) team from Costa Rica, which participated in this workshop. The information shared and problems identified and analysed in the workshop will assist the MRSD-team in improving their sustainable development models for Costa Rica with respect to the issue of sustainable water supply and sanitation.

Dr. Harry Buikema,
Director ETC-Netherlands.

P.O.Box 64,
3830 AB Leusden,
The Netherlands,
Tel: +31 33 4943086,
Fax: +31 33 4940791,
E-mail: office@etcnl.nl

Foreword by ETC Programme manager on Urban Agriculture Programme

Dear participants,
Due to unforeseen obligations I was not able to attend the Workshop on Sustainable Municipal Waste Water Treatment Systems. I find this very unfortunate, especially after hearing of the success of the workshop. I would, however, like to use this opportunity to share with you some information on the Urban Agriculture activities of ETC to which the workshop has a direct relevance.

ETC has committed itself to provide support for activities on sustainable urban agriculture. Urban agriculture is increasingly recognised as a practical, realistic and desirable land use option in urban areas and an integral part of the urban productive system.

Urban agriculture we understand as food and fuel grown within urban areas and includes crop production and animal production on roadsides and along railroads, in back yards, on roof tops, within utilities rights of way, in vacant lots of industrial estates, on the grounds of schools, prisons and other institutions, etcetera; aquaculture and poultry production in tanks, ponds and rivers; orchards and vineyards; street trees, backyard trees, and trees on steep slopes and along rivers; as well as the recycling and use of urban organic wastes (waste water and solid wastes) as resources.

The potential of urban agriculture for enhanced food security, employment creation and small enterprise development, environmental management and productive use of urban wastes, is being acknowledged. ETC intends to further promote the application of sustainable urban agriculture in which the reuse of waste materials from urban centres will form an integral part. The ETC approach underwrites the notion that urban wastes should be approached as a resource (converting open loop "disposal" systems in closed loop "re-use" systems).

For all of you working with integrated waste water treatment systems, urban agriculture most probably is or could very well be a key aspect of the system.

In that case the Resource Centre on Urban Agriculture and Forestry (RUAF) could provide valuable information on crop, tree and animal production. In return your experience will be relevant for Urban Agriculture experts around the world. RUAF is a project that will be coordinated by ETC, in the context of the Global Facility on Urban Agriculture.

The growing recognition of the importance of Urban Agriculture is reflected in the establishment of the Global Facility on Urban Agriculture (GFUA) in March 1996. GFUA is an inter-agency and management unit established with support from UNDP, IDRC, FAO and around 30 other international organisations. GFUA underlined the need for the development of Urban Agriculture through applied research, information exchange and documentation, policy formulation, in combination with training, technical assistance, and investments.

More information on GFUA partners and their activities is provided on Internet:
http://www.idrc.ca and cityfarmer.org/GlobalFac1.htm#globa.

To operationalise the information and communication section of the Action Programme of the GFUA, a project called "Resource Centre on Urban Agriculture and Forestry" (RUAF) was formulated by ETC in co-operation with TUAN and other GFUA members. RUAF will be managed by IDRC (under the "Cities feeding people" programme), while ETC will be the leading implementing organisation. ETC will co-ordinate the participation of 6 regional focal points and of other GFUA members. The initial phase of the project will last three years, starting April 1997.

The objectives of RUAF are:

- ☐ To improve access of local stakeholders in urban agriculture to documented experiences in the field of crop production, forestry and animal production in urban and peri-urban areas, improved land use and the re-use of urban wastes for productive purposes (the closing of polluting open loop systems)
- ☐ To respond to the information needs regarding Urban Agriculture of national and local governments, funding agencies, and other support organisations, and to facilitate policy uptake.
- ☐ To support the development of national and regional networks on Urban Agriculture and to facilitate South-South communication and co-operation between networks and associated organisations.
- ☐ To strengthen the capacity of selected key institutions in developing countries to collect and disseminate information on project experiences and research results on Urban Agriculture.
- ☐ To facilitate analysis of selected themes that are seen as crucial for the development of Urban Agriculture and the removal of roadblocks.

Project activities include the publication of an electronic newsletter, the organisation of electronic conferences, the establishment of a data base and resources directory on urban agriculture, a RUAF-website on the Internet and support to regional networking and information exchange regarding Urban agriculture.

RUAF will be implemented by the ETC office in Leusden, the Netherlands. However, the regional offices of ETC in the Andes (La Paz and Lima), India (Delhi, Bangalore), East Africa (Nairobi), Sri Lanka (Colombo), and Zimbabwe (Harare) will be involved in Urban Agriculture research, policy advice, consultancy and training.

We are looking forward to some kind of co-operation in the future.

Henk de Zeeuw,
Urban Agriculture Programme Manager,
ETC-Netherlands.

P.O.Box 64,
3830 AB Leusden,
The Netherlands,
Tel: +31 33 4943086,
Fax: +31 33 4940791,
E-mail: office@etcnl.nl

Foreword by ETC workshop coordinator

Organising a workshop with participants from many different countries like the one reported on here is a difficult and time consuming task. Whether or not the outcome is a success can only be determined after the event. For me this workshop was successful, because we managed to facilitate a lively discussion among all participants on the subject of sustainable waste water treatment systems. This strengthens my conviction that the methodology used (written contribution to the discussion and visualisation of results) is an appropriate tool for facilitating participation from everyone.

I did not organise this workshop alone. A number of people provided assistance and support, without which the workshop could not have been so successful. I would like to thank a number of people, in particular:

First I would like to thank the initiators of the workshop, Winfried Rijsenbeek, Frank van der Vleuten, and Rob Lichtman. Secondly Pieter Lammers of ECOOPERATION and Joep Bijlmer of DGIS/DRU/UO for their confidence in us and their support in obtaining required financial support for this workshop. Together with these donors I should also thank Harry Buikema of ETC and Jaap Rijnsburger of WASTE for the substantial in kind contribution in the organisation and execution of the workshop. Herbert Aalbers I would like to thank for his work in the preparation for this workshop and both Herbert and Annelies Balkema for their assistance during this workshop, Further I would like to thank Joost van Buuren (WAU), Siemen Veenstra (IHE), Gerard Rijs (RIZA) and Jaap Rijnsburger (WASTE) who took the time to discuss the approach for conducting this workshop.

I would like to thank my colleagues at ETC for their help in preparing and conducting this workshop and their flexibility regarding lunch times and other disturbances we may have caused. I would also like to thank COKZ (Centre body for quality aspects of dairy products), our neighbours for providing us with great workshop accommodation.

Finally, of course, I would like to thank all participants who so actively participated in the discussions. Discussions were sometimes emotional, but never without respect for each others opinion. A special thanks goes to those participants who volunteered to preform specific tasks during the workshop such as the chairpersons and the moderators of group-discussions.

I am looking forward working with you all again.

Enno Heijndermans,
Workshop Coordinator.

P.O.Box 64,
3830 AB Leusden,
The Netherlands,
Tel: +31 33 4943086,
Fax: +31 33 4940791,
E-mail: office@etcnl.nl

Foreword by WASTE

The NGO WASTE is a Dutch based consultancy on Urban Environment and Development, with local partnerships in Peru, Costa Rica, Mali, Pakistan and Philippines. A few years ago WASTE initiated UWEP, the Urban Waste Expertise Programme. UWEP, with financing of the Dutch Department of International Cooperation (DGIS), aims at mobilizing and developing South expertise on urban waste issues. Expertise to improve the living environment of million-city dwellers. Expertise to enhance the generation of income out of waste collection, waste recycling and waste management. Expertise which, explicit or dormant, is part and parcel of the many urban livelihood systems in which waste is not wasted, in which waste is a resource, in which waste is solid income. Expertise which can respond to the demands for improvement from cities elsewhere. Expertise which, once recognized and preserved, can be extended in a waste management based on prevention and reuse, and assist to improve environment and living conditions in multi-million cities, South and North.

In UWEP, WASTE doesn't differentiate between wastes. In low income areas without planned infrastructure and collective facilities, both solid and liquid wastes need to be stored in the house, need to be collected to prevent accumulation, need to be treated and disposed to prevent disease transmission and public nuisance. The handling of both solid and liquid wastes generates income, both can be a valuable resource in waste recycling And, particularly in low income urban areas where solid wastes are composed of more than 50% organic material, solid and liquid are mere appearances of organic mass, opening up other ways to treat and use a resource.

WASTE recognizes the great value of, community and small enterprise based, sub-systems that are substantial in the solid waste sector: pre-collection of household wastes and recycling of waste fractions (e.g. plastics, batteries). These sub-systems are extremely important elements in the urban waste management. Their character: low investment, labour intensive, neighbourhood scale, employing "social tissue". One of the subjects in UWEP is to survey parallels sub-systems for liquid waste, in particular the neighbourhood scale: decentralized collection and treatment of house hold generated excreta and waste water. This activity has the prosaic acronym UWEP08.

When ETC asked us to join in the hosting of a workshop on sustainable waste water treatment, we sensed a tremendous opportunity to get together with a selection of experts from many countries and continents and share their experience and insights with respect to a less conventional approach towards liquid waste. Real life experience and an open mind to non-conventional solutions are tributes towards the agenda of UWEP08. Also we invited a number of South experts to the workshop, with whom we are already collaborating on the subject, or with whom we expected to be able to collaborate in future.

This preface is not the appropriate place to evaluate the contents and conclusions of the workshop, but I cannot disguise my enthusiasm about the rich mix of experience, vision, expertise and persona lity that merged in Leusden. A merge with continuation, for which UWEP08 can provide some fuel, and benefit. It also shows the fruitfulness of the joint effort between ETC and WASTE. A one time effort, yes, but it develops taste for more ....

Jaap Rijnsburger,
Managing Director,
WASTE, Advisors on Urban Environment and Development

Nieuwehaven 201,
2801 CW Gouda,
The Netherlands,
E-mail (personal): rijnsburger@waste.nl
(general): office@waste.nl
Fax: +31 182 550313,
Tel: +31 182 522625.

Part I: Papers

1.1 Technology Selection For Pollution Control, *S. Veenstra and G.J. Alaerts.*

International Institute for Infrastructural, Hydraulic and
Environmental Engineering IHE, P.O. Box 3015,
2601 DA Delft, The Netherlands,
Tel: +31 15 2122921,
Fax: +31 15 2151776,
E-mail: sve@ihe.nl

(adapted edition from: Water Pollution Control. R. Helmer ed. Chapman and Hall, London, to be issued in 1996)

1.1.1 Integrating wastewater and water management

Economic growth in most of the world has been vigorous, especially in the so-called newly industrialising countries. Nearly all new developments create stress on the "pollution carrying capacity" of the environment. Many hydrological systems in the developing regions are, or are getting close to, being stressed beyond repair. Industrial pollution, uncontrolled domestic discharges in particular from urban areas, diffuse pollution from agriculture and livestock-rearing, and various alterations in land use or hydro-infrastructure lead to non-sustainable use of water resources, eventually leading to negative impacts on the economic development of many countries or even continents. Lowering of groundwater tables (middle east countries), irreversible pollution of surface waters and associated changes in public and environmental health are typical manifestations of this development.

Environmental technology development has kept pace with this economic development; the number of available technologies and their performance have improved substantially. However, technological development is frequently not (yet) conceived from a sustainability point of view. Treatment technologies in industrialised countries tend to focus on centralised collection by sewerage and end-of-pipe treatment. This is at the expense of huge resource requirements in terms of finances, materials, energy, land acquisition etc. that cannot easily be afforded in many developing countries.

Instead of investing in end-of-pipe technology, it is advised to investigate whether pollution can be minimised or even prevented. Cleaner production technologies within industries and minimisation of waste flow generation are frequently more cost-effective and sustainable.

Identification of conceivable alternatives and selection of technology for urban planners, decision makers and industrial engineers seem to pay off. From a planning perspective several questions need to be addressed before any hard-ware technology choice is to be made:

- Is wastewater treatment a felt priority in public or environmental health ?
- Is treatment contributing to sustainable environmental development ?
- Can pollution be minimized by alternative technologies or public awareness ?
- Is treatment most economical at centralised or decentralised facilities ?
- Can the intrinsic value of generated resources be recovered ?

Ultimately, for each pollution problem a strategy is to be developed that is most appropriate with respect to technical acceptability, sustainability, economic affordability, and social attractiveness. This pertains to developing as well as industrialising countries. Taking notice of the rapid urbanisation of the population in many developing and industrialising countries emphasis in this paper will be on the urban environment. Pollution and population stress is felt most in these densely populated areas and in particular in the peri-urban environment low income settlements and industrial zones do contribute to further deterioration of all environmental compartments as there are water, air and soil.

Technologies in developing countries where capital is scarce and unskilled manpower abundant, solutions should preferably be low-cost oriented. This commonly implies that the technology chosen is less mechanised, has a lower degree of automatic process control, and that construction, operation and maintenance aim to involve locally available manpower rather than imported mechanised components. In reverse, such technologies are land intensive.

The final technology selection may involve three major categories of criteria:

1. the treatment objectives imposed on the effluents (quality criteria and guidelines)
2. matching technology requirements to locally available resources and conditions
3. the degree of sustainability of a technology in a particular location

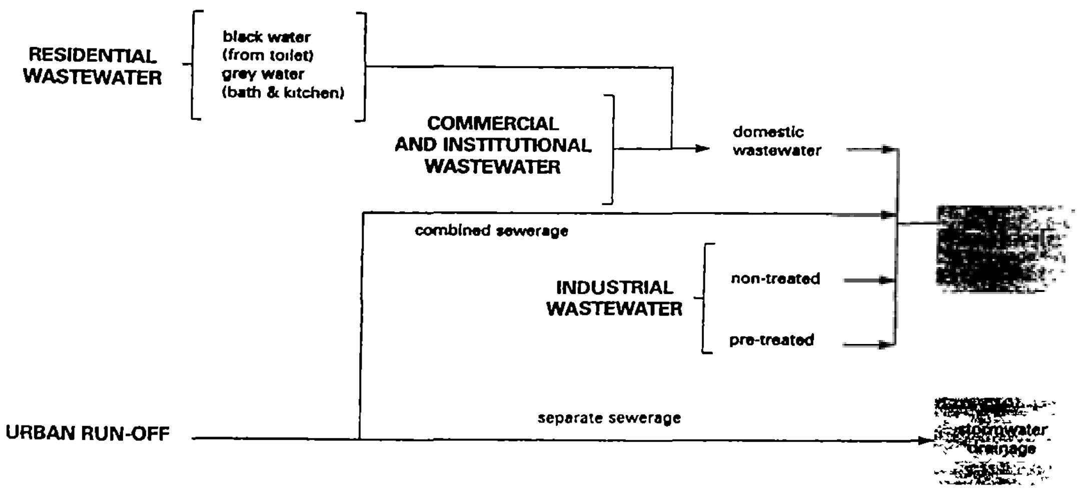


Figure 1: Origin and flows of wastewater in an urban environment.

1.1.2 Wastewater origin, composition, and significance

1.1.2.1 Wastewater flows

Municipal wastewater is typically originating from domestic and industrial sources and may include urban run-off (Fig. 1). The *domestic* wastewater is generated from residential and commercial areas, including institutional and recreational facilities. In the rural setting, industrial effluents and stormwater collection systems are less common (although polluting industries find the rural environment attractive for uncontrolled discharge of their wastes).

In rural areas the sanitation problem is mainly associated to pathogen-carrying faecal matter. Industrial wastewater commonly originates from designated zones or, as in many developing countries, from numerous small-scale enterprises incorporated within residential areas. Diffuse urban pollution is primarily created by street run-off and by the overflow of combined sewers during heavy rainfall; in the rural context it arises mainly from agricultural run-off carrying pesticides, fertiliser and suspended matter, as well as manure from livestock.

In the household, tap water is used for a variety of purposes, such as washing, bathing, cooking and transport/flushing of wastes. The *black* wastewater from the toilet, and the *grey* wastewater from the kitchen and bathroom can be disposed of separately or combined. Generally, the wealthier a community, the more water is used for toilet flushing and personnel cleansing. Consequently, this development imposes a threat to sustainable water resources management and generates wastewater flows that can not be adequately disposed of on-site. Collection, transportation and offsite treatment are required, which conflict seriously with the concept of sustainable development as it involves large investments in displacement of the pollution load. Domestic wastewater generation is commonly expressed in litres per capita per day (lcd) or as a percentage of the specific water consumption rate. Domestic water consumption, and hence wastewater production, typically depend on community size (urban/rural), water supply service level, climate and water availability (Table 1). In moderate climatic and industrialised countries typically 75% of consumed tap water ends up as sewage; in more arid regions this ratio may be less than 50 % due to high evaporation and infiltration rates and typical domestic water use practices.

Table 1: Typical domestic water supply and wastewater production (lcd)in industrial, developing, and (semi) arid regions.

Water supply service	Industrial regions	Developing regions	(Semi) Arid regions
□ handpump or well	n.a.	<50	<25
□ public standpost	n.a.	50 - 80	20 - 40
□ house connection	100 - 150	50 - 125	40 - 80
□ multiple connection	150 - 250	100 - 250	80 -120
Average wastewater flow	85-200	65-125	35-75

Industrial water demand and wastewater production is sector-specific. Industries may require large volumes of water for cooling (power plants, steel mills, distillation industries), processing (breweries, pulp and paper mills), cleaning (textile mills, abattoirs), transporting products (beet sugar mills) and flushing wastes. Depending on the production process the concentration and composition of the waste flows can vary significantly. Particularly in industrial wastewater the wide variety of micro contaminants add to the complexity of treatment; combined treatment may reduce the overall removal efficiencies but high unit cost for treatment (U$/m^3).

Repetitive flow and load fluctuations in industries can be quite considerable depending on in-plant procedures: production shifts, workplace cleaning, etc. As a consequence municipal treatment plants may get confronted with varying loading rates which may reduce their overall removal efficiency. In particular a high degree of hazardous or slowly biodegradable contaminant removal requires a constant loading rate and smooth operation of the treatment plant to ensure process and performance stability. General policy with respect to industries should be that they are forced by legislation to even out peak flows and adequately reduce the concentrations of potential toxic compounds to avoid any risk of imbalance of the municipal treatment plant performance. Moreover, removal of specific contaminants from industrial waste flows on-site may be more cost effective and efficient than its removal from a highly diluted municipal sewage flow. Typical domestic peak flows (in the early morning and in the evening) can easily be handled in municipal wastewater treatment works.

1.1.2.2 Wastewater composition

Municipal wastewater can be characterised by its main contaminants (Table 2). These may exert negative effects on the aqueous environment in which they are discharged. As treatment systems usually are devoted to remove basic contaminants only their performance may deteriorate in the presence of industrial hazardous contaminants. Therefore municipalities may have to set additional criteria prior to accepting industrial waste flows into their sewer in order to avoid oils, heavy metals, ammonia, sulfide, or micro toxic constituents to create dramatic effects on sewer corrosion, or treatment plant performance.

Table 2: Major classes of municipal wastewater contaminants, significance, and origin.

Contaminant	Significance	Origin
Settleable solids (sand, grit)	Settleable solids may create sludge **deposits** and anaerobic conditions in sewer, treatment facility or open water.	Domestic, run-off
Organic matter (BOD); Kjeldahl-nitrogen	Biological degradation consumes oxygen and may disturb the **oxygen balance** in surface water; if the oxygen in the water is exhausted anaerobic conditions, odour formation, fish kill and ecological imbalance will occur.	Domestic, industrial
Pathogenic microorganisms	Severe public health risks through transmission of communicable **water borne diseases** such as cholera.	Domestic
Nutrients (N and P)	High levels of nitrogen and phosphorus in surface water will create excessive algal growth (**eutrophication**); dying algae are organic matter (see above)	Domestic, rural run-off, industrial
Micro-pollutants (heavy metals, organics)	Non-biodegradable compounds which are **toxic, carcinogenic or mutagenic** at very low Level (to plants, animals, humans); they may bio-accumulate in the food chains, examples are chromium(VI), cadmium, lead, most pesticides and herbicides, and PCBs.	Industrial, rural run-off (pesticides)
Total dissolved solids (salts)	High levels may **restrict sewage use** potential for agricultural irrigation or aquaculture.	Industrial, (salt water intrusion)

They contaminate the sewage and render it unfit for any productive use. Several technologies allow selective removal and recovery up to high purity if applied on the concentrated waste streams, thereby covering part of the investment cost. For instance, in textile mills pigments and caustic solution can be recovered by ultra-filtration and evaporation, while chromium (VI) can be recovered by chemical precipitation in leather tanneries. In other situations, sewage can be made suitable for irrigation or reuse in industry.

Domestic waste production per capita is fairly reproducible but the concentration of the contaminants varies with the amount of tap water consumed (Table 3). In Sana'a, Yemen it is five times more concentrated than in Latin American cities where water consumption is around 300 lcd. In addition, infiltration of groundwater may take place as the sewerage system may not be watertight. Similarly, many sewers in urban areas collect the overflows of septic tanks which affect the influent sewage quality. Depending on local conditions (degree of road pavement) and habits (level of nutrition, staple food composition, kitchen habits, etc.) waste parameters may need correction. The sewage composition may be fundamentally altered if industrial discharges are allowed into the municipal sewerage system.

Table 3: Ranges of domestic waste load and consumption.

Contaminant	Specific Production (g/cap.d)	Concentration (mg/l)[1]
Total solids: dissolved	100 - 150	400 - 2500
Total solids: suspended	40 - 80	160 - 1350
BOD	30 - 60	120 - 1000
COD	70 - 150	280 - 2500
Kjeldahl-nitrogen (as N)	8 - 12	30 - 200
Total phosphorus (as P)	1 - 3	4 - 50
Faecal coliform (no/100 ml)	$10^6 - 10^9$	$4.10^4 - 2.10^8$

[1] Assuming water consumption rate of 60-250 lcd.

1.1.3 Wastewater management

1.1.3.1 Treatment objectives

Technology selection eventually depends upon wastewater composition and on the treatment objectives translated into effluent quality criteria. The latter depends on the expected use of the receiving waters: public health protection (recreation, irrigation), preservation of the oxygen content in the water (prevent odour release), prevention of eutrophication (odour and fish kill), prevention of clogging (navigation), avoid toxic compounds entering the water and foodchains (fishing, nature conservation), and opting for water re-use in aquaculture or agriculture (Fig. 2). These water uses are translated into emission standards or, in many countries, water quality 'classes', i.e. pertaining to describe the desired quality of the receiving water body. The setting of emission or effluent standards may incorporate technical and/or financial aspects. Therefore they may differ between various countries. Table 4 offers typical discharge standards as applied in industrialised and developing countries.

1.1.3.2 Classification of sanitation solutions for domestic sewage

The increasing world population tends to concentrate in urban communities. In these densely populated areas the sanitary collection, treatment and disposal of wastewater flows are essential to control the transmission of water borne diseases, to prevent non-reversible degradation of the urban environment itself, and protect the aquatic systems that supports the hydrological cycle, the food production and the biodiversity in the region surrounding the city. For rural populations -- accounting for 75% of the total population in developing countries (WHO, 1992) - concern for public health is the main justification to invest in water and sanitation improvement. In both settings, the selected technologies should be environmentally **sustainable** (that is: meet the prescribed effluent quality), **appropriate** to the local conditions, **acceptable** to the users, and **affordable** to those who have to pay for them. Simple solutions that are easily replicable, that allow further upgrading, and that can be operated and maintained by the local community are often considered the most *appropriate and cost-effective*.

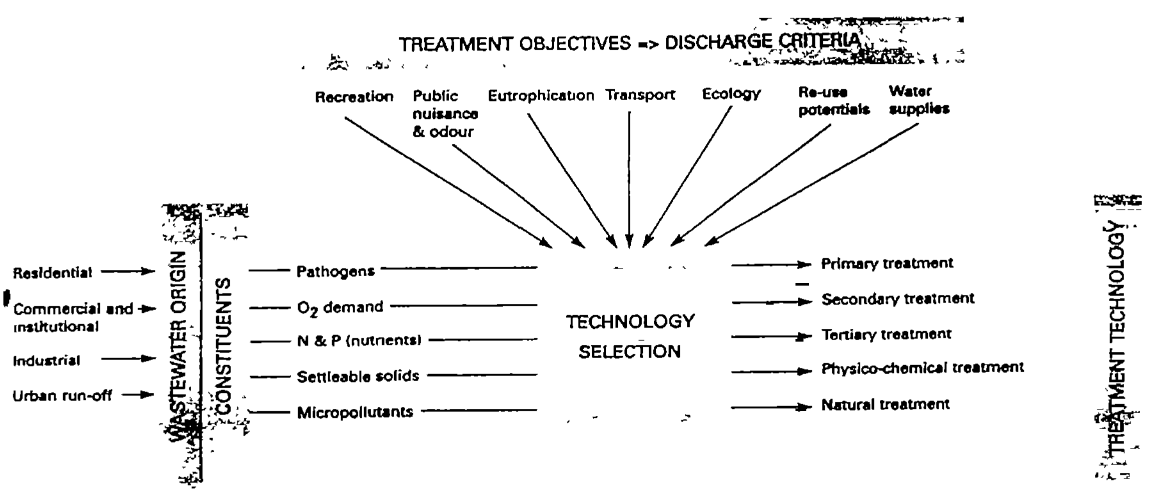


Figure 2: Treatment technology selection in function of wastewater origin, its constituents, and formulated treatment objectives as derived from the set discharge standards.

The first issue to be addressed is whether sanitary treatment and disposal should be provided at on-site level (at the level of a household or apartment block), or whether collection and centralised, off-site treatment is more appropriate. The main deciding criteria are population density (persons per ha) and wastewater flow (m^3/ha.d). The wastewater flow is directly related to the water consumption which is defined by the water supply service level. The population density affects the availability of land for o n-site sanitation and has impact on the unit cost for

Table 4: Treated effluent standards as function of intended use (data on wastewater use in irrigation taken from FAO (1976) and WHO (1989)) ([1] Agronomic norm).

		Discharge in surface water High Quality	Low Quality	For discharge in waters sensitive to eutrophication	Effluent use in irrigation and aquaculture
BOD	mg/l	20	50	10	100 [1]
TSS	mg/l	20	50	10	< 50 [1]
Kjeldahl-N	mg/l	10	-	5	-
Total N	mg/l	-	-	10	-
Total P	mg/l	1	-	0.1	-
Faecal coliform	/100ml	-	-	-	$< 10^3$
Nematodes eggs	/l	-	-	-	< 1
SAR	-	-	-	-	< 5
TDS (salts)	mg/l	-	-	-	< 500

Table 5: Gradual development of wastewater treatment plants in the industrial countries; a smooth process of upgrading to meet increasing effluent standards.

Period	Treatment objective	Treatment	Operations included
1950/60s	suspended/coarse solids removal	primary	screening, removal of grit, sedimentation
1970s	organic matter degradation	secondary	biological oxidation of organic matter (BOD)
1980s	reduce nutrients (eutrophication)	tertiary	reduction of effluent total N and total P
1990s	micro-pollutants	advanced (or quartiairy)	physico-chemical removal of micro-pollutants

off-site sanitation. Dry and wet sanitation systems can be distinguished by whether water is used for flushing the solids and convey them through a sewerage system. The present trend for increasing specific water consumption (in lcd) in combination with the rising urban population densities create a strong interest in wet off-site sanitation as the main future strategy for wastewater collection, treatment and disposal.

In many urban situations off-site solutions are considered the only solution as the soil does not allow for percolation of large quantities of wastewater. In addition, the associated risks of groundwater pollution, reported from many cities in Africa and the Middle East, is prohibitive for on-site sanitation. An intermediate technology has emerged which is a mix of on-site sewage collection in a septic tank followed by off-site disposal of settled effluent through so-called 'small bore sewers' (or 'shallow sewers'). The settled solids in the septic tank need periodic removal. The advantage of this system is that the unit cost of small bore sewerage is substantially lower. In addition groundwater pollution is prevented. The system lends itself particularly well for densely built-up areas (Sinnatamby, Mara and McGarry, 1986).

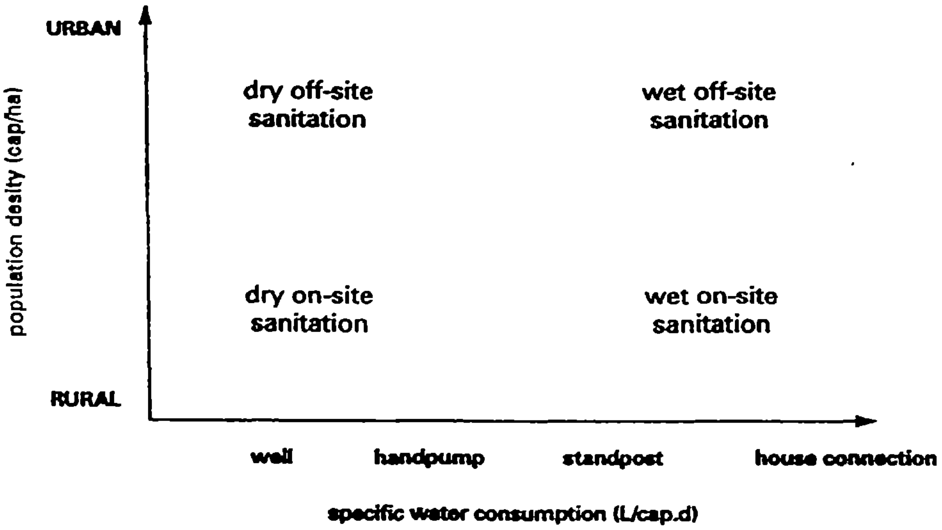


Figure 3: Classification of basic sanitation strategies in function of population density and wastewater flow (water consumption). The current trend is from dry on-site to wet off-site sanitation (see arrow).

1.1.3.3 Level of wastewater treatment

To achieve water quality targets an extensive infrastructure needs to be developed and operated. In order to get industries and domestic polluters to pay for the huge cost involved in such infrastructure legislation is to be set up based on the principle: "the polluter pays". Treatment objectives and priorities have gradually increased in industrialised countries over the past decades. This resulted in the first, second and third generation of treatment plants characterised by improved removal rates (Table 5).

This step-by step approach allowed for a gradual tightening of the 'treatment objectives', and timewise definition of what the desired effluent quality entails, and how these can be reached by a particular technology at full scale. As a consequence existing treatment plants were continuously in the process of expansion and upgrading; primary treatment plants were extended with a secondary stage in the 1960s, while secondary treatment plants are nowadays considering tertiary or even quartiairy treatment.

In general, the number of available treatment technologies, and their combinations, is nearly unlimited. Each pollution problem calls for its specific optimal solution involving a series of unit operations and processes put together in a flow diagram (Table 6).

■ *Primary treatment* generally consists of physical processes involving mechanical screening, grit removal and sedimentation, aiming at removal of oil and fats, settleable suspended and floating solids; simultaneously at least 30% of BOD and 25 % of TKN and Total P are removed. Faecal coliform numbers are reduced with 1-2 log units only, whereas 5-6 are required for making it fit for agricultural reuse.

Table 6: Common classification of treatment processes.

Primary	Secondary	Tertiary	Advanced
Bar or bow screen	Activated sludge	Nitrification	Chemical treatment
Grit removal	Extended aeration	Denitrification	Reverse osmosis
Primary sedimentation	Aerated lagoon	Chem precipitation	Electrodialysis
Comminution	Trickling filter	Disinfection	Carbon adsorption
Oil/fat removal	Rotating bio-discs	(Direct) filtration	Selective ion exchange
Flow equalisation	Anaerobic treatment/UASB	Chemical oxidation	Hyperfiltration
pH neutralisation	Anaerobic filter	Biological P removal	
Imhoff tank	Stabilisation ponds	Constructed wetlands	
	Constructed wetlands	Aquaculture	
	Aquaculture		

■ *Secondary treatment* mainly converts biodegradable organic matter to carbon dioxide, water and nitrates, by microbiological processes. These aerobic processes require oxygen which is usually supplied by intensive mechanical aeration. For sewages with relatively elevated annual temperatures anaerobic processes can also be applied. In this case the organic matter is converted into a mixture of carbon dioxide and energy rich methane.

In primary and secondary treatment sludges are produced with a volume less than 0.5 % of the wastewater flow. Heavy metals and other micro-pollutants tend to accumulate in the sludges as they often adsorb onto suspended particles. Nowadays the problems of wastewater treatment are gradually shifted from wastewater treatment itself towards treatment and disposal of the generated sludges.

Non-mechanised wastewater treatment by stabilisation ponds, constructed wetlands or aquaculture using macrophytes can to large extend provide adequate secondary and tertiary treatment. As the biological processes are not accelerated by mechanical equipment large land areas are required to provide sufficient retention time to allow for a high degree of contaminant removal.

■ *Tertiary treatment* is designed to remove nutrients comprising total N (kjeldahl-nitrogen, nitrite and nitrate) and total P (particulate and dissolved) from the secondary treated effluents. Additional suspended solids and BOD removal is achieved by these processes. The objective of tertiary treatment is to reduce the risk of eutrophication in sensitive surface water bodies.

■ *Advanced or quartiairy treatment* such as ion exchange, adsorption, hyperfiltration, precipitation as well as oxidative disinfection and detoxification processes are applicable only for industrial wastes to remove specific contaminants. Commonly advanced treatment is preceded with physico-chemical coagulation, flocculation and filtration. Where a high quality effluent is required for groundwater recharge, advanced treatment may as well be added to conventional municipal wastewater treatment plants. Table 7 reviews the degree to which contaminants are removed by treatment processes or operations. Most treatment processes and operations are only truly efficient for the removal of small variety of pollutants.

1.1.3.4 'Best Available Technology'

In taking precautionary or preventive end-of-pipe treatment measures, authorities may by statute require the polluter, notably industry, to rely on the best available technology (BAT), the best available technology not entailing excessive costs (BATNEEC), the best environmental practices (BEP) and the best practical environmental option (BPEO).

The BAT is generally accessible and effective in preventing or minimising pollution emissions. It can also refer to the most recent development stage of a particular technology. Assessing whether a certain technology is the best available requires comparative technical assessment of treatment processes, its facilities and methods of operation which have been recently successfully applied for a prolonged period of time at full scale.

The BATNEEC adds an explicit cost/benefit analysis to the notion of best available technology. 'Not entailing excessive cost' implies that the financial cost should not be excessive in relation to the financial capability of the industrial sector concerned, and to discharge reductions or environmental protection envisaged.

The best environmental practices and the best practicable environmental options have a wider scope. BPEO requires identification of the least environmentally damaging manner for discharge of pollutants while demanding the use of treatment processes is to be based upon BATNEEC. BPEO policies also require that the treatment measures avoid transferring pollution or pollutants from one medium to another (from water into sludge). BPEO integrates the account for cross-media impacts of the technology selected to control pollution.

1.1.3.5 Selection criteria

The general criteria for technology selection comprise:

(i) *Average, or typical, technical efficiency and performance* of the technology. In comparative studies this is the first opportunity to reduce the number of options to be taken into consideration. However, the pathways and fate of the removed pollutants after treatment need to be analysed, especially with regard to the difficulty for disposal of micro-pollutant contaminated sludges.

(ii) *Reliability* of the technology. The process should preferably be stable and resilient against shock loading. It should be able to continue operation and produce an acceptable effluent under unusual conditions. The system must accommodate the normal variations in the working conditions, as well as infrequent yet expected more extreme conditions. This pertains to the wastewater characteristics (occasional illegal discharges, variations in flow, pollutant concentrations, and temperatures, etc.) as well as operational conditions (power failure, pump failure, poor maintenance, irregular operation etc.). In the design phase 'what to do if' scenarios should be considered. Once disturbed, the technology should be fairly easy to repair and restart the process.

(iii) *Institutional manageability*. In developing countries few governmental agencies are adequately equipped for wastewater management. In order to plan, design, construct, operate and maintain treatment plants appropriate technical and managerial know-how needs to be available. This requires the availability of sanitary engineers with post-graduate education in wastewater engineering, access to a local network for research and scientific support to allow problem solving, access to moderate quality laboratories, and experienced staff in utility management and cost recovery. In addition, all technologies, also those thought 'simple', require devoted and experienced operators and technicians who need to be generated through education and training.

(iv) *Financial sustainability.* The lower the financial costs, the more attractive the technology. However, even a low cost option may not be financially sustainable as this is determined by the true availability of funds provided by the polluter. In the case of domestic sanitation, the people must be willing and able to cover at least the operation and maintenance cost of the total expenses. The ultimate goal should be full cost recovery though this may need special financing schemes in the beginning, such as cross-subsidisation, revolving funds, and phased investment programmes.

(v) *Application in re-use schemes.* Resources recovery contributes to environmental as well as financial sustainability. It can include agricultural irrigation, aqua- and pisciculture, industrial cooling and process water re-use, or low-quality applications such as toilet flushing. Sludges can only be considered for crop fertilisation or land reclamation if its micro-pollutant level is not prohibitive, or health risk imposed to the workers and consumers are not acceptable.

(vi) *Regulatory determinants.* Increasingly, regulations with respect to desired water quality of receiving waters are determined by what is considered as technically and financially feasible. The regulatory agency then imposes the use of specified, up-to-date technology (BAT or BATNEEC) upon domestic or industrial dischargers, rather than prescribing the required effluent discharge standards.

1.1.4 Pollution prevention and minimisation

Over the past years, awareness grew that many of the end-of-pipe technologies were not the most sustainable way to achieve a clean environment. Waste problems were transported from one compartment to the other. For example, end-of pipe treatment technologies transfer hazardous compounds from the water phase into a sludge or gaseous phase. After sludge disposal, migration of pollutants into the soil and groundwater may occur. As a result, the approach is now shifting from waste management to pollution prevention and waste minimisation, which is also referred to as *cleaner production.*

Pollution prevention covers an array of technical and also non-technical measures. It is advocated to be most effective to achieve improved water quality. Cleaner production is the conceptual approach to industrial production that demands that all phases of the *product life cycle* be addressed with the objective to prevent or minimise short and long-term risks to humans and the environment.

Cleaner production emphasises the prevention of waste and pollutant generation. Not only industrial production process, but also the product design phase, the selection of raw materials, the production, packaging and assembly of final products, and finally the management of all used products at the end of their useful life is to be incorporated. This **life cycle analysis** approach will reduce the generation of wastes. Losses of raw material and other useful resources are minimised, thereby contributing to sustainable environmental development and substantial financial savings.

Waste minimisation involves not only technology but also planning, good house-keeping, and implementation of environmentally sound management practices. Many obstacles however prevent the introduction of these technologies in existing or even in new facilities: insufficient awareness of the environmental effects of the production process, lack of understanding of the true actual costs of waste management, no access to the latest technical know-how, insufficient knowledge of the implementation of new production technologies, lack of financial resources, and last but not least, social resistance to change in general. By the principle " the polluter pays" industries are specifically encouraged to:

(i) prevent waste production by intervening in the production process,
(ii) reduce the generation of hydraulic and organic peak loads that may render a municipal treatment system more expensive or vulnerable, and
(iii) treat their waste flows to meets discharge requirements, to prevent damage to the municipal sewer or realise cost savings for the discharge onto municipal treatment plants.

Table 7 provides examples of discharge limitations into municipal sewers. The method applied in The Netherlands to calculate waste discharge fees is provided in box 1.

Table 7: Typical regulations for industrial wastewater discharge into a public sewer system in the United Kingdom and Hungary (Appleyard 1992, UNECE 1984).

Parameter	United Kingdom	Hungary
pH	6 - 10	6.5 - 10
Temperature (°C)	< 40	—
Susp. solids (mg/l)	< 400	—
Heavy metals (mg/l)	< 10	specific
Cadmium (μg/l)	< 100	< 10,000
Total cyanide (mg/l)	< 2	< 1
Sulfate (mg/l)	< 1000	< 400
Oil and grease (mg/l)	< 100	< 60

1.1.5 Sewage conveyance

1.1.5.1 Storm water drainage

In many developing countries storm water drainage should be part of wastewater management as large sewage flows are carried into open storm water drains. In industrialised countries stormwater management receives substantial attention as it may be polluted by sediments and heavy metals, and it may upset the secondary and tertiary treatment steps.

In urbanised areas the local infiltration capacity is usually not sufficient to absorb peak discharges of storm water. Large flows often have to be transported in short periods (20-100 minutes) over long distances (500-5,000 m). Drainage cost is to large extend determined by the actual flow rate of the moment and therefore retention in reservoirs to reduce peak flows allows the use of smaller conduits, thereby lowering areal drainage cost. In industrialised countries new reflections are being advocated to locally use these excessive rainwater resources for local suppletion of surface waters or for groundwater infiltration. The advantages are both, no substantial disturbances of wastewater treatment plants and no costly conveyance system required for stormwater. In tropical countries, with their characteristic seasonal rainfall pattern infiltration may not be feasible during the wet season as the soil is fully saturated, especially in areas with high water table or low soil permeability.

Box 1: Calculation of the financial charges for industrial pollution in The Netherlands are based on standard 'population equivalents' (PE).

Population Equivalents' (PE):

The PE-load of industrial discharge:

$$PE=\frac{Q*[COD+4.57*TKN]}{136}$$

Q	=	wastewater flow rate (m^3/day)
COD	=	24 hours-flow proportional COD concentration (mg COD/l)
TKN	=	24 hours-flow proportional Kjeldahl-N concentration (mg N/l)
136	=	waste load of 1 domestic polluter (136 g O_2 consuming substances/d and by default set at 1 Population Equivalent).

Heavy metal discharges are separately charged :
- each 100 g Hg or Cd/d = 1 PE,
- each 1 kg of total other M/d (As, Cr, Cu, Pb, Ni, Ag, Zn) = 1 PE.

An annual charge of US$ 35-50 (1994) is levied by the local Water Pollution Control Boards; the charge is region specific and relates to the Board's overall annual expenses.

1.1.5.2 Separate and combined sewerage

In separate conveyance systems, storm water and sewage are conveyed in separate drains and sanitary sewers, respectively. Combined sewerage systems carry sewage and storm water in the same conduit. Sanitary and combined sewers are closed to not impose any public health risks. In Europe conventional sewerage coverage ranges from 45% in Greece to 98% in The Netherlands; in Japan it is only 20-30 % though increasing, whereas in the U.S. the coverage rate is just 50 %.

Separate systems require investment in, and operation and maintenance of two networks. However, they allow the design of the sanitary sewer and the treatment plant at much lower *peak* flow. In addition a more constant and concentrated sewage is fed to the treatment plant, which favours the reliability and consistent process performance. Therefore, even in countries with moderate rainfall intensities new residential areas incorporate separate sewerage systems. Combined sewerage is not common in developing countries because:

(i) it requires simultaneous investments in drainage, sewerage and treatment, and
(ii) it requires soil erosion control for unpaved areas.

Advantage of combined sewerage is that the first run-off, which tends to be heavily polluted, is treated along with the sewage. Sewage treatment plants are typically designed to accommodate

2-5 times the average dry weather flow, which obviously raises the treatment cost and adds to the complexity of process control. Extreme peak flows cannot be handled; they are discharged directly onto surface waters. These sewer overflows can create serious water quality problems which can be specified in time and space.

Sanitary sewers are feasible only in densely populated areas as unit cost per household decrease to acceptable levels. Although most street sewers carry only small amounts of sewage, construction cost is high because it requires a minimum depth to protect them against traffic loads (minimum soil cover of 1 m), a minimum slope to ensure self-cleansing, and a minimum diameter to prevent blockage by faecal matter and other solids (diameter preferably > 25 cm). Flushing velocities of 0.6 m/s once a day are ensured when tap water consumption rates are in excess of 60 lcd.

To reduce costs, sewerage may use smaller diameters, may be installed at lower depth, and may apply a milder gradient. However, this requires entrapment of settleable solids in a septic tank prior to discharge into the sewer. Such small-bore sewers are only cost-effective if maintained and sustained by the local community. Small-bore sewers may ultimately discharge into a municipal sanitary sewer or a treatment plant. In low-density flat areas with unstable soils small-bore pressure or vacuum systems can be applied.

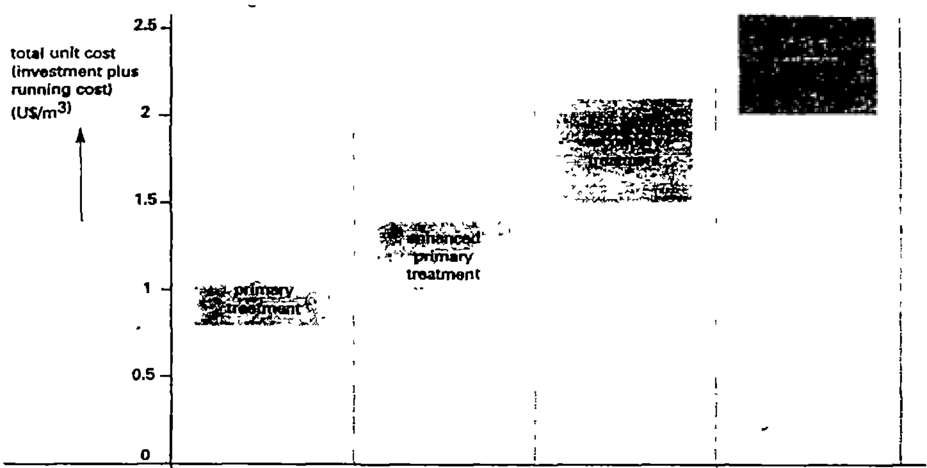
Successful examples of low-cost small bore sewerage projects are reported from Brazil, Colombia, Egypt, Pakistan and Australia. At population densities in excess of 200/ha these small-bore sewer systems tend to become cost effective over on-site sanitation. The Environmental Government Service in Sao Paolo (SABESP) estimates the average construction cost (1988 prices) for small towns to be U$ 150 - 300 /cap for conventional sewerage and U$ 80 - 150 /cap for simplified small-bore sewerage (Bakalian et al, 1994). Septic tanks and cess pits are regularly to be desludged by the owners to avoid failure of the technology. Cases from Indonesia and India demonstrate that overflowing septic tanks are typically illegally connected to public drains or sewers and that during desludging only the liquid portion is removed, while the solids are retained in the septic tank. Therefore, substantial investments are to be put in community involvement in order to ensure its sustainability.

1.1.6 Costs and operation and maintenance

Investment costs cover notably the cost of land, groundwork, electro-mechanic equipment, and construction. Recurring costs pertain notably to the paying back of loans, and the costs for manpower, energy and other utilities, stores, laboratories, utility management, repair and sludge disposal. Both types of cost may vary considerably from country to country, as well as with time and level of technology applied (Fig. 4). Any financial feasibility analysis requires the use of proper discount factors. This factor depends on inflation and interest rates and is subject to substantial fluctuations. Therefore, comparing various technologies is always difficult and requires extensive expert analysis.

Operation and maintenance is essential in wastewater management; hence it will affect technology selection. Many wastewater projects fail, or perform poorly, once constructed because of inadequate O & M. On annual basis, the O&M expenditures of the treatment system and of the sewage collection system, are typically of the same order of magnitude as the depreciation on the capital investment. O & M requires (i) careful exhaustive planning, (ii) a qualified and trained staff devoted to its assignments, (iii) an extensive and operational system to have available spare parts and O&M utilities, (iv) a maintenance and repair schedule, crew and facility, (v) a management atmosphere that emphasises the importance of a continuous high level of service with a minimum of interruptions, and (vi) a substantial annual budget that is uniquely devoted to O&M and service improvement.

The most common reasons for O&M failure are (i) inadequate budgets to cover running cost due to inadequate cost recovery, (ii) poor planning of servicing and repair activities, and weak spare parts management, and (iii) inadequately trained operations staff.



removal in %				
BOD	30	50-70	90-95	>95
TSS	60	80-90	90-95	>95
TN	15	25	40	>80
TP	15	75	90	>90

Figure 4: Typical unit cost data for wastewater treatment based on West European and US experience (Somlyody, 1993).

1.1.7 Selection of sanitation strategy and technology

With respect to choices to be made in sanitation strategy and technology selection most developing countries can more easily fit into one of the basic concepts of sustainable technology development which states that separation of waste streams and selection of subsequent technologies that suit most the individual characteristics of each waste stream is by far more sustainable that the common industrialised country approach of putting it all together in one combined sewer system. The flexibility created by early segregation also provides a wider scope for applying a combination of technologies that can be implemented in an overall urban sanitation strategy.

Technology selection is a result of multi-criteria analysis considering technological, environmental, financial, logistic and institutional factors within a planning horizon of 10-20 years. Key input factors are the size of the community to be served; the existing sewerage system; the sources of wastewater; the opportunities for pollution prevention; the effluent discharge standards; the availability of local skills; and environmental conditions such as land availability, geography and climate. Considerations for specific industrial treatment technology selection are beyond the scope of this paper.

1.1.7.1 On-site sanitation technologies

For domestic wastewater treatment, the appropriateness of sanitation options need to be related to the type of community into: rural, small town or urban (Table 8). Typically in low-income rural and (peri-)urban areas on-site sanitation systems are most appropriate as they are (i) low-cost due to the absence of sewerage, (ii) allow construction, repair and operation by the local community, and (iii) reduce effectively public health problems.

Black water is commonly disposed in pit latrines, soakaway or septic tanks (Fig. 5). The effluent infiltrates into the soil or seeps into a drainage system. The accumulated septage in the pit or tank (approximately 40 L/cap.year) need to be removed periodically or a new pit has to be dug (dual-pit latrine). The sludges are well stabilised and after a retention of at least 6 months it may be considered free from pathogens, and can be used as fertiliser/soil conditioner in agriculture.

Grey water can be directly infiltrated or can flow into drainage channels or gulleys as its suspended solid content is low. The grey water in particular lends itself easily for irrigation purposes as its degree of pollution is moderate and it does not expose serious health hazards

In densely populated urban areas the generation of wastewater may exceed local infiltration capacities. In addition, the risk of groundwater pollution and soil destabilisation often necessitate off-site sewerage. At on-site hydraulic loading rates in excess of 50 mm/day and less than 2 m unsaturated groundwater flow in vertical direction nitrate and possibly in a later stage fecal coliform contamination is due to arise (Lewis et al, 1980).

The unit cost for off-site sanitation decreases significantly with increasing population density but sewering an entire city often proves to be too expensive. In cities where urban planning is uncoordinated implementation of a balanced mix of on-site and off-site technologies for various city clusters or 'barios', is typically most cost-effective. For example, in Latin America

Table 8: Classification of residential areas in rural, small township or urban and their corresponding sanitation options.

	RURAL	TOWNSHIP	URBAN
Community size	< 10,000	10,000 - 50,000	> 50,000
Density (cap/ha)	< 100	100 < x < 200	> 200
Water supply	well, handpump; < 50 L/cap.day	public standpost; 50-100 L/cap.day	house connection; > 100 L/cap.day
Sewage production	< 5 m^3/ha.d	5 < m^3/ha.d < 20	> 20 m^3/ha.d
Treatment options	dry on-site sanitation by VIP or composting latrines	dry and wet on-site sanitation; small bore sewerage may be feasible	Centre: off-site sewerage + treatment; Peri-urban: wet on-site sanitation with small-bore sewerage and septage handling

the population density at which small-bore sewerage becomes competitive with on-site sanitation is approximately 200 capita per hectare (Sinnatamby et al. 1986).

Figure 5: Sanitation systems classification in on-site and off-site (based on population density) and in dry and wet sanitation (based on water supply) (Kalbermatten et al. 1980).

Chart 1 may provide guidance in preliminary decision making regarding on-/off-site sanitation. Technical, financial and logistic criteria, and reliable management by a local community based entity or local government are essential to ensure its sustainable use by the beneficiaries.

Most off-site treatment technologies benefit from economies of scale. Notably anaerobic technologies, in particular its UASB application, tend to easily scale down to township level or even less without seriously rising the unit cost. This makes them suitable for inclusion in urban sanitation. This 'community on-site' option may ensure a more disciplined operation and desludging as compared to the performance of individual home-owners, whilst retaining the advantage that it can be managed by a local committee and semi-skilled caretakers. This makes UASB technologies attractive in combination with small bore sewerage.

Chart 1 provides some guidance for preliminary decision making between on-site and off-site sanitation. In case of high wastewater production per ha per day, sewerage plus off-site sewerage is advised to either dispose off the liquids only (in case of small-bore sewerage), or the liquid plus suspended solids (in case of conventional sewerage).

Additional decisive parameters are whether groundwater used for water supplies need to be protected from pollution, soil permeability and comparative cost analysis. To minimise groundwater pollution a maximum applicable long term infiltration rate of 20 $l/m^2/d$ at 50 m^2/ha used for infiltration (corresponding to a wastewater production of 10 $m^3/ha.d$) is recommended (Lewis et al, 1980) provided that prevailing groundwater tables ensure at least 2 m unsaturated flow in vertical direction.

When wastewater production rates exceed 10 $m^3/ha.d$ conventional sanitary sewerage may be required. The technical feasibility of conventional sewerage is commonly ensured if minimum sewage flow velocities of 0.6 m/s can be produced at least once a day to resuspend and flush the solids to the end-of-pipe. This requires a per capita wastewater production rate > 65 L/cap.day. Studies indicate that at around 200 - 300 capita/ha conventional sewerage becomes economically feasible in developing countries; whereas this is around 50 cap/ha in industrialised countries.

If groundwater protection is no priority, the local infiltration potential may exceed the 10 $m^3/ha.d$ if soil permeability and stability allows. If soil permeability is low off-site sanitation needs reconsideration. Depending on the socio-economic environment and the degree of community involvement that can be generated small bore sewerage may be feasible. In that case additional stormwater drainage infrastructure is to be provided.

1.1.7.2 Off-site sanitation

A large variety of off-site technologies are available. The final technology selected will be decided by the wastewater composition. Is industrial wastewater included ?, is separate or combined sewerage applied ?, is there groundwater infiltration ?, are septic tanks removing suspended solids prior to discharge ?, what is the specific water consumption ?, what is the tap water quality ?, the food pattern ?, etc. All these questions are to be addressed in order to assess the basic composition of the raw sewage.

Each urban sanitation strategy always needs to be composed of a combination of technologies in such a way that it matches the local conditions and criteria best. The same applies for the composition of the required off-site technology. Unit processes and operations are systematically and logically to be put together to establish a well balanced treatment scheme which will be able to meet the required effluent criteria. Commonly off-site technologies are composed of primary, secondary, and tertiary or advanced unit operations and processes.

□ Primary unit operations and processes

In most treatment plants mechanical primary unit operations and processes proceed subsequent biological and/or physico-chemical treatment. It involves removal of oil, grease, sand, grit, fibres, and other coarse objects. Primary treatment may also serve to equalise peak flows, to adjust the pH, and notably to remove settleable suspended or floating solids. Overall typically 50-75% of suspended matter, 30-50% of BOD and 15-25% of TKN and Total Phosphorus are removed at moderate cost.

Physico-chemical processes may be incorporated in primary treatment to enhance the removal efficiencies. Typically, coagulation and flocculation using Al or Fe salts is applied. Such enhanced treatment is comparatively low in investment cost but expensive in running cost due to the consumption of chemicals; it is an attractive method to temporarily expand a treatment plant capacity which may occasionally (seasonally) be overloaded with organic pollution.

□ Secondary treatment

The most common technology used for secondary treatment of wastewater relies on (micro)biological conversion of oxygen consuming substances such as organic matter, represented as BOD or COD, and Kjeldahl-N. The technologies can be distinguished mainly in aerobic and anaerobic technologies based on whether oxygen is required for their performance, or in mechanised and non-mechanised system depending on the intensity of mechanised input required (Table 9).

The discussion between aerobic and anaerobic technologies will mainly have to address the added complexity of oxygen supply which is needed in aerobic technologies. The supply of

Table 9: Classification of secondary treatment technologies.

Deciding criterium	Mechanised technology	Non-mechanised technology
Aerobic conversion	Activated sludge Trickling filter Rotating bio-contactor	Facultative stabilisation ponds Maturation ponds Aquaculture (eg algal ponds, duckweed ponds, fish ponds) Constructed wetlands
Anaerobic conversion	Upflow Anaerobic Sludge Bed (UASB) technology Anaerobic (upflow) filter	Anaerobic ponds

large amounts of oxygen via surface aeration or bubble dispersion system substantially adds to the capital cost for aeration equipment as well as to the running cost as the annual energy consumption is rather high; it can go up to 30 kWh per Population Equivalent (PE).

The discussion between mechanised and non-mechanised technologies relates to the locally or nationally available technological infrastructure which may ensure a regular supply of skilled labour, local manufacturing, operational and repair potential for used equipment, and reliability of supplies (power, chemicals, spare parts etc.). Additional key considerations are the land requirements and the potentials for biomass resource recovery. In general non-mechanised technologies need to provide substantial longer retention times to achieve a high degree of contaminant removal whereas mechanised systems use equipment to accelerate the conversion processes. If land costs are in excess of U$ 20 non-mechanised systems lose their competitive cost advantages over mechanised systems. With respect to resource recovery reference is made to the production of algal or macrophyte biomass (duckweed, water hyacinth etc.) that may become a marketable product generating revenues and local labour. For example, constructed wetlands using *Cyperus papyrus* may generate annually around 40 - 50 ton standing biomass per ha which can be used in handicraft or other artesian activities.

For non-biodegradable (mainly industrial) waste waters technologies have been developed that are more tailored to the physico-chemical removal potentials of contaminants by coagulation and flocculation. The generated sludges are typically heavily contaminated and have no potentials for reuse other than landfilling.

Overall the selection process for the most appropriate secondary technology may have to be decided upon by multi-criteria analysis. In addition to the overall unit costs, the environmental, aesthetic and health risks involved, the quality standards to be met, the skilled staff and land requirements, the reliability of the technology at its potentials for recovery scenarios all may be valuated providing a total score which then indicates the feasibility of each technology for a particular country or location (Handa et al, 1990).

Natural off-site treatment technologies deserve priority consideration over mechanised treatment. Typically natural treatment systems can be operated easily and maintained at local level without reliance on imported equipment or specialised skilled operators.

Their main disadvantage is the high land requirements. At land prices beyond U$ 20/m^2 natural systems loose their competitiveness over mechanised treatment according to a study for the World Bank (IBRD Workshop, 1993). Natural treatment includes waste stabilisation ponds (Table 9), constructed wetlands, and aquaculture aiming at recovery of biomass (water hyacinth or duckweed of fish) at simultaneous removal of wastewater pollutants.

In particular these natural treatment systems may better match the local available skills and expertise as they do not heavily rely on mechanical energy input, like mechanised systems such as activated sludge, trickling filter and RBC. However, the attractiveness of these natural treatment systems is largely determined by the land cost which are rather high. Typical indications are that land requirements are at least 10 times higher (5-10 m^2/PE) than conventional activated sludge or trickling filter systems (0.5 -1 m^2/PE). Land costs in excess of U$ 20/m^2 were considered prohibitive for natural treatment unless resource recovery can yield economic benefits (biomass harvesting and/or opportunities for effluent reuse (IRBD Workshop, 1993).

Key considerations in the selection of secondary treatment processes are effluent quality, land and energy cost, potentials of resource recovery and level of experienced skills available. These parameters and others will be used in guiding the selection between biological and physico-chemical treatment, aerobic or anaerobic treatment, and natural versus mechanised treatment.

Biological and physico-chemical processes both can achieve significant BOD, P and suspended solids removal. For wastewater with a high organic matter content, like domestic sewage, biological methods are commonly preferred as they have lower operational cost and higher removal performance; large fractions of the organic material are dissolved and hence are poorly removed by flocculation. Physico-chemical treatment, therefore, is generally not the preferred option. It is typically applied in industrial wastewater treatment for the removal of specific contaminants or to reduce the bulk pollutant load to the municipal sewer, and in advanced treatment to reduce phosphorus. Flocculation can also be applied within primary treatment to temporarily enhance removals and reduce the load on the subsequent secondary treatment step.

Table 10: Typical advantages and disadvantages of physico-chemical domestic waste water treatment.

Advantages	Disadvantages
□ compact unit operation with low area needs	□ chemical dosing is labour intensive due to fluctuating sewage load and composition
□ good removal of micro-pollutants and P	□ generation of chemical sludges
□ fast start up procedure	□ unit cost per m^3 are high
□ no sensitivity to toxic matter	

The skills required to operate chemical dosing equipment, and the difficulty to ensure reliable supply of chemicals are often prohibitive for physico-chemical treatment in developing countries; systems are more prone to malfunctioning. In particular the fluctuating flow and composition of the incoming sewage makes frequent adjustments of the chemical dosing necessary. Biological treatment systems are more sturdy, and ensure a constant effluent quality as they have a high internal buffering capacity for peak flows and loads (Table 10).

■ *Anaerobic technologies*

Aerobic technologies have traditionally dominated domestic and industrial wastewater treatment. Since the 1970s, however, anaerobic treatment has come the preferred technology for organic wastewater from breweries, alcohol distilleries, fermentation industries, canning factories, pulp and paper mills, etc. (Hulshoff Pol and Lettinga 1986). In particular the Anaerobic Upflow Sludge Blanket (UASB) technology is most cost-effective for most types of industrial wastewater.

The choice between aerobic and anaerobic technologies depend primarily on the sewage characteristics. If the average sewage temperature is above 20 °C (with a minimum of 18°C for a maximum duration of 2 months) *and* the sewage is highly biodegradable (COD/BOD ratio > 2.5) and concentrated (typically BOD > 1000 mg/l), anaerobic technologies demonstrate clear economic advantages over aerobic treatment. If neither condition is met aerobic treatment is more feasible.

If only one condition is met the ultimate choice is determined by additional considerations:

- the desired effluent quality
- the cost saving in sludge handling and disposal
- the possibility of effluent reuse
- reliability of power supplies
- the local potentials for biogas valuation.

When high effluent standards are to be met, and when land cost is moderate to high, the combination of UASB plus aerobic post-treatment is often decisively more cost-effective than conventional aerobic treatment.

World wide over 400 UASB plants treat industrial wastewater flows, while 10 full scale UASB plants (size 20,000-200,000 cap) in Colombia, Brazil and India is documented (Alaerts et al., 1990; Schellinkhout and Collazos, 1992; Draaijer et al. 1992; van Haandel and Lettinga, 1994). Whereas aerobic processes achieve 90-95% removal on BOD, the UASB achieves only 75-85% necessitating, in most cases, post-treatment to meet effluent discharge standards. Anaerobic treatment systems have low sludge production rates but hardly reduce N and P levels of the effluent. Biogas recovery is only feasible in an industrial context. Many developing countries give preference to anaerobic technologies because of the numerous agro-industries and the often high domestic sewage temperatures.

■ *Non mechanised treatment*

The availability of flat land is a decisive criterion in selecting between mechanised and non-mechanised technologies. Land-extensive systems such as waste stabilisation ponds, aquaculture systems and constructed wetlands require typically 5-10 m^2PE which may only be considered feasible if land cost are below U$ 10/m^3. They are fairly simple in operation and maintenance provided the wastewater is of domestic origin, fit better to resource recovery because the biomass produced can -if harvested- generate labour and income. Algae based stabilisation ponds are in operation on all continents although they suffer sometimes from disturbances caused by sulfide, ammonium, or high suspended solids content in the final effluent.

In aquaculture systems and constructed wetlands macrophytes are cultivated to suppress algal growth. They absorb nutrients and assist in the transfer of oxygen into the water phase. In aquaculture with floating duckweed (Lemnaceae) offers good prospects as its abundant growth can be easily harvested. In constructed wetlands wastewater is made to flow either horizontally or vertically through a permeable soil or gravel media planted with vegetation. The plants, -if regularly harvested-, create a sink for the nutrients by their uptake and assimilation. More importantly, they provide suitable niches for bacteria that enhance BOD reduction, nitrification, denitrification, P fixation and pathogen removal.

At high land cost (indicative: U$ $\geq$ 15-25/m^2 according to the IRBD (1993)) the investment cost for mechanical equipment in compact mechanised technologies are completely offset by the high cost for land acquisition by non-mechanised technologies. In fact provision of land to allow for algal growth compensates for the energy requirements ($\approx$15-25 kWh/PE.year) to provide mixing and oxygen supply.

■ *Aerobic mechanised technologies*
If flat land is scarce or expensive and anaerobic technologies are not feasible the remaining options is to use conventional compact aerobic mechanised technologies. These can be divided according to their sludge retention in fixed biofilm reactors or suspended growth systems with sludge recycle. The advantage of biofilm reactors over suspended growth systems is that biomass is better retained in the reactor and can therefore better resist hydraulic fluctuations and low BOD concentrations. On the other hand, suspended growth systems are easier to control and generally produce better quality effluent. However, the degree of operational control for biofilm reactors is fairly limited and their effluent quality often can not meet the standards (Table 11). Trickling filters have poor N and P removal, while rotating bio-discs are not widely applied because of low operational flexibility and mechanical problems. Suspended growth technologies allow more flexible process control and generally produce a higher quality effluent throughout the year.

Typical suspended growth technologies are the activated sludge system; in particular new design concepts try to accommodate extra potentials for nutrient removal. Trickling filters and rotating bio-discs are biofilm based technologies. The activated sludge system in its various designs is the most widely applied technology, offering operational flexibility, high reliability and resilience.

Table 11: Performance comparison between trickling filter and activated sludge system.

Parameter	Trickling Filter	Activated Sludge
BOD removal (%)	80 - 95	90 - 98
Kjeldahl-N removal (%)	60 - 85	80 - 95
Total N removal (%)	20 - 45	65 - 90
Energy required (kWh/cap.year)	10 - 15	20 - 30
O&M requirement	medium	high
Pathogen removal	1-2 log units	1-2 log units

If pathogen removal is essential only non mechanised technologies featuring hydraulic retention times of 10 - 20 days can provide satisfactory removal of faecal coliform and nematode eggs to meet WHO guidelines (1989). All compact mechanised technologies need additional chemical disinfection. This adds to the overall treatment cost and the operational complexity of the treatment plant, and will ultimately reduce the reliability of the treatment plant to provide 'safe effluents' for irrigation schemes.

1.1.8 Conclusions and recommendations

World wide there is a repositioning taking place with respect to sustainable water resources management in the future. Conservation of water resources (quantity and quality wise) is more and more emphasised in order to address the anticipated and increasing shortages of water resources of good quality in many parts of the world to meet the ever increasing domestic, industrial and agricultural demands. Extrapolation of the increased water consumption rates over the last 10 years will for sure create huge shortages in many populated areas of the world; in particular in the arid and semi-arid world regions.

This means that solving sanitary problems of human and industrial waste flows - in particular when generated in urban environments - may in the future not be automatically be feasible by water consuming technologies which rely on conventional sewerage carrying and transporting the suspended waste particles away from the place where they are generated.

Water saving technologies, water recycling and reuse will get more dominant in the future and will reallocate the attention from pollution control (emission policy) to waste prevention and waste minimisation (immission policy). Scenarios with potential recovery of valuable resources will get promoted as they become more feasible in the context of sustainable water resources management.

Seeing the world wide urbanisation taking place the attention for water and sanitation will more shift to the densely populated urban and peri-urban areas where new incentives are created for technology development that will address people with marginal financial resources available and too low water supply service levels to ever justify conventional sewerage.

Separating wastewater flows (black and grey water, domestic and industrial wastewater, sewage and rainwater) and development of technologies that aim to recuperate these individual wastewater flows and make them fit for reuse or recycling, will in the long run contribute to sound water resources management and simultaneously reduce public health risks and environmental pollution as it will reduce the appeal on the pollution carrying capacity of the available environment.

Technology selection for waste flows may therefore have to take a broader perspective than only meeting the present discharge standards as formulated for the present situation. Anticipating the above trends might stimulate the use of an additional criterium in technology selection that is: sustainable use of scarce resources whether it be water, nutrients, energy or space.

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P.O.Box 8, Ozumba,
56800, Edo, Mexico,
Tel: +52 55797060,
Fax: +52 59554344,
E-mail: xochical@data.net.mx

1.2.1 Summary and recommendations

This integral project takes advantage, articulates, a series of today underemployed and/or rejected local resources, "trying to loose" them and, in many cases, contaminating us; it enhance mutually every those to sustain a harmonic development with the environment. Given the complex community problematic, we face holistic solutions, synergetic, creative and people´s participation ones, that recreate the interest and make possible that the members of any community will be real and transcendent actors of his future projected, without importing resources, based on those which today already have.

The thick-headedness "academist, technificist and constructivist - machinicist" that "sustains" **the conventional technologies** of waste-"treatment", falls in mathematical theory "demonstrative" of his truth, wrong as we will see and actually live; makes of the deep cognizant real specialists of it less, ignoring the complexity of the reality, blinding with plans where they have privileged a totally myopic vision of the problems, since they **can not violate a law of Physics**, *"nothing is created nor destroyed, only is transformed"*, changing the pollution of a side to other; then try to concentrate particles and muds with physical & chemical methods (air bubbling, activated sludge recirculation, settlement, scum-floating and flocculation promoters, design, etc.), leaving water without them, but sending them to the soil and/or subsoil to "sanitary " landfills that contaminate much more thanks to such concentration of dangerous not stabilized products, releasing them trough lixiviated liquids that generate and/or react with the rain or yet dampness of the environment; then, trying don´t to obtain septic conditions (that upon acceding to the acidogenic phase generate sulphydric that stinks) inject air with multitude of machines, many and more sophisticated while are more "modern" and "of top" is the technology, generating a lot of a series of gases (NOx, COx, SOx, VOS, chlorinate volatile compounds, ammonia, etc.) that they can or to return to the soil and water as acid rain, or to stay in the atmosphere provoking attack against the O_3 layer and enhance the greenhouse effect..... and even so, the quality commonly is very poor and is out of the regulations (NOM in our country). Said simple, the historical model tries to hide from our senses - sight, smell, tact and pleasure - the wastes .... but polluting, as if our system would be opened: our planet practically only exchanges energy, the "material things" are here for ever. So adding more machinery and chemicals **"intend" to ignore another law of physics**: *"each time is added an additional step to a physical process (and every are), it increases the entropy."* Since this is a form of useless energy, it is a measure of the inefficiency, greater when are added more steps, more pollutant so .... they try to make us to believe in "magic solutions" of "black box", but of enormous cost in money - social - environmental and dependency that we should pay to build and operate: **they augment really the pollution and spend of -wasted- resources.** ***That's why they are so expensive to buy and, particularly, to operate.***

Xochicalli had demonstrated, demystify so wrong, 'anti -participate'; anti - economic, vertical, costly and absurd "solutions" in the followed road, proposing and promoting alternatives as the SUTRANE ® and the Microplant ® systems. The challenge and recommendation is to build many to validate them, to improve they, to adapt and to spread them, always with communitary -diverse: population, local government, academic institutions, etc.- participation approach.

Their development was based on several facts:

A) Technically.- Thanks to the experiences on the SUTRANE ® (unitary system to treat and reuse of water, nutriments and energy) that Xochicalli completion since the early '70s, today in multiple sites and different shapes, sizes, etc. Once it was installed in the scale of some 10 families together, were perceived the limitations:

- Land size. Require wide spaces for the secondary biophysical filter-field; when it is made shared, who puts the area for this wishes but products upon beginning to obtain them, the same as the families but numerous, etc. Also it is caused that as our country (and all those of world) is being making urban -at the beginning of century 80 % of the inhabitants was rural, around the end of same, 80 % will be urban- this imposes us solutions in the cities, knowing that we have solved the problem in the rural areas; however our approach is that of to intercept the tour of the problems near its origin: Microplants ® instead of macroplants; Dual to recover resources instead of single (only water) and of transfer of both problems.

- Is required a devoted and intense managing of crops, so much in the sowings aspect, distribution, etc.

- Once you have greater volumes of digester and matter to load, you can obtain more biogas, though its quality is some poor, because is feded with human excreta. From there the convenience of including in the ration cellulose debrys, domestic solid wastes, etc., to improve getting better quantity and quality.

B) Environmentally.- Upon existing thousands of drainage transferring, disseminating and increasing the pollution problems.

C) Scientifically.- Thanks to the knowledge of the indicated laws of physics. Always the conventional processes are spending energy and resources to burn other resources (!).

D) Economically.- Since they are losting systematically the resources that contain the wastes, spending money and resources on transferring them, to the time of trying that we to believe that it is difficult, complex and expensive, impossible for the community to participate in something.

E) Socially. - As everybody provide to the pollution and this is very democratic (no matter who originate it, to all of us reaches), so we should collaborate to our cause: to solve it. As now is focused as something distant and foreign, always it is thought about third. person: "should be done this or that thing; the government had to . .; how do they pollute so much here!"; etc.

1.2.2 Objective

A) General. To intercept the tour of the problems, giving productive treatment initially to the liquid wastes and in the (near) future to the solid ones.
B) Specific. Take advantage of the water, nutriments and fertilizes recovered to produce certain foods and other plants that benefit first the local economy and later......
- to train to the community in the constructive and operative ecotechniques in order to dimish costs (labour and use), aside from to permit the multiplication of the microplants through design of Xochicalli in other places -there or in other sites- of similar groups involved.

Interpretation.- What is exposed and the corruption (since one of the best businesses is the sewage pipe building: it is expensive to construct, maintain, operate and repair-re do, in addition to that is impossible to see to audit) motivate technical personnel thick-headedness and political urging the constructions and the operation; transfer and increase in the pollution and the waste, making every time but difficult the decontamination for cost and impossibility of be actors. In a genial planet, designed self-sufficient (alone exchanges energy), it is absurd that today subsist such lags. Our Microplant ® intercept, treat, separate and reinsert in every productive cycles what today is useless, they enhance the social participation since the planning. On the other hand, by the commercial opening the wrong technological penetration is serious: credit close packages at low loan rates lesser than the one which is procured in Mexico + work of plants of pseudo treatment. Which Municipal President will be opposed?

Building microplants in universities we could investigate, show the technology and to adapt training methods to several scales, not only that of ecological houses and their components (example: the SUTRANEs), including social groups, municipal governments, NGOs, etc., coinciding their social development, independent struggle and interest on their environment and economy with those of Xochicalli, beginning the complementary relationship that derived with the beginning of the training and construction of the microplant and, to future, of recycling microindustries to generate employment, add value and increase the capitalization rapidity, against what actually happen: we loose $ and pollute us.

Beneficiary population
Benefited inhabitants for which the plant is builded and thousands that are waters down of the work place, since is a gradual decontamination; it is impossible to estimate the quantity. Their long struggles is that our technology permit to develop and to recover some cultural features such as the "tequio" (community voluntary work), social activities division, cooperative of consumption, etc.

Most of our technology solicitants are several groups belong to popular bases of independent organizations left or right, though with affinity with the Parties of the Democratic Revolution (left) and National Action (right). As they are in today's opposition, this permits to them to exercise greater political pressure through widely supported mobilizations, though at the same time with wide reticences and rejection of many dependencies and bureaucrats. Anyway actually the facts, reality and our performance are pushing to many other groups, municipalities, etc., of the official party or independent -academic, private enterprises, food producers, etc.

1.2.3 Institutional framework

A)The design of Xochicalli, in base to the experiences of the former some similar microplants (Ozumba and Texcoco, State of Mexico; Janitzio, S. Of Michoacan and, particularly, Puebla), as well as with the participation of some members of the communities with experience in the projects of their own works, help to confront what goes occurring, thanks to their design.

Actual law indicates that who urbanizes must treat the rejected waters or to pay the call "ecological tax", depending on the contributions of BOD and TSS, reaching -1995- an average of \$1.20/m^3 at domestic level. In our strategy the community will be the owner, administering the recovered resources.

B) The federal government, through the National Commission of the Water (CNA), controles the operation, fixes the regulation and grants the permits, grants, etc.; the state water commission and reparation (CEAS) approves the project and supervises the construction - operation; the municipal government grants the construction permit and it is who provides the drinking water; the social development secretary gives the seen good to the technology and supervises that is fulfilled the standard, investigating the cases in which is violated. In this case a federal funds combination, state and municipal, so much in depth lost as in the form of credit, serve to pay little but of half of the work. Xochicalli designs, it provides the adequate technology (according to the law of the state), trains in the work and the operation, administers and supervises the work and provides advising on specific problems; additionally it procures graduate programs that they support the future development of the operation, particularly in what is referring to the managing of the cultivation in greenhouses and in green areas. The organized community provides their labor hand for the construction, so much trained as without training; provide the area that I buy for the work, some material and management. The decisions within the communities are taken by consensus as well as by voting, giving agility to the processes and depending on the importance. In the case of the microplant, are consulted, had together with different companies and visits to several treatment plants. After that they express their decision of the fact that we collaborate, they have been spending months to pressure years against multitude of technical personnel and political, a reticence mixture to the change and certain cohabitations to protect businesses (already cited and but forward).

C) Each project there can or not to receive previous external supports or during the project process, work or even during his operation.

D) Xochicalli from before has had relationship to the instances of participating government.

E) According to what is noted, the principal conflicts are derived from conceptions and traditional managings, added from what is complex of the fund that it has been obtained, having to satisfy several federal bureaucracies, state and municipal, and financial organizations. Technical several have insisted on a conventional and complete presentation of all the aspects of the technology, same that Xochicalli it has insisted at the same time that alone delivery through agreements that specify responsibilities to have control over the design.

F) Given the problematic complex of the all pollution urbanization new must count on a treatment plant that treat their drainage. In the case of the law of protection of the ambient of the state of Mexico (in which we participate) is indicated that it must be of appropriate technology, stimulating the community participation, permitting the resources recovery in the wastes to recycle them and without transferring (to generate) gases, smells, muds, etc., to the ambient. Furthermore it is feasible to integrate it in a future with the solid wastes managing, dual. Furthermore they should comply with the new procedures to reuse of the water treated in irrigation systems.

1.2.4 Description of the system

A) **The water arrives** to a pretreatment closed and at once passes to the multiple anaerobic digestion system for the one which the muds are reduced to the ½% of what is usual; the effluent treaty passes to a multichanel where is oxigenated and filtered making to grow plants that fix but energy, the same as those which are put on the biophysical chemical filter, for then be stung together with the organic waste and to feed to the digesters; it is there can potabilize a part and be reused. All the system is inserted in a greenhouse. It does not bid farewell smells, gases neither creates health care problems. We see:

B) As already is indicated, this technology developed by Xochicalli seeks the decentralization and the community participation from the preparation of the investment project (to see annex graph) until the operation. Though seeks the appropriation of the productive systems and of the utilization operation of the recovered resources, it is not easy the design case by case and its calculate, therefore this part is the support that offers Xochicalli. When it exists a good organization that seeks to use the discussed water and the nutriments obtained, is designed of manner of integrating a greenhouse climatised on it and annex several that are built in terraces ex - professo, those which are cultivated intensively with flowers, vegetables, spices and medicinal. In the green areas between the houses also it is considered take advantage what is recovered and to sow other plants of the same cited type, aside from you hoist fruit-bearing of size and adequate variety.

The microplant has capacity for from 500 until modules of some 15,000 hab., that it grows in as many units as will be necessary consists of: pretreatment with sieve, settlement tank -sand trap and hatch; catabolic digester (disagregate complex forms in simple), anaerobic filter of contact and complex flow (3 rapid flow stages), anaerobic digester horizontal settlement tank; filter multichannel aerobic with aquatic plants; filter bio-physical-chemical aereador-vertedor with stony material sections of granulometry controlled (zeolitas above all); recollector for effluents utilization with dropper of excesses. Climatizer greenhouse and for natural photocatalisis.

C) Commonly is considered that the technology of the treatment of the wastes is so complex that no community can participate; also and since they are not seen as resources, that nothing have to do with in their manage. For us is exactly to the contrary: the technology, in certain important parts, designed to permit and enhance said participation; thus the people that operated the work knows as this fact and will know as operates, permit that care it better, above all if, as is our approach, they recover the resources that today they are losing, thus permitting their reinsertion to productive cycles, adding local value and making what is revenue-yielding to them. However they are imposed restrictions to their opened transfer: they are established exchange agreements that clarify the complementary relationship in the short, average and long term, so much in what is collective and what is individual and in what is monetary and in what is social.

1.2.5 The impacts of the action

Before beginning the works, given the great participation that is sought with what is various of the contributions and transcendence of the project - since they visit and discuss multiple alternative - and of the activities and bordering productive works, the satisfaction level upon seeing other of the similar works of Xochicalli operating is extremely high. Given the process followed to take the decisions, the social control - democratic this covenantee, facilitating the technological appropriation. The community will be taken charge of the maintenance operation and use of the effluents, being transacted the grant of the water.

The Xochicalli plants occupy between 5% and 50% of the earthly of the others; they can be adapted to plants recyclers of garbages. For these plants the maintenance is take advantage and to sell what transforms the microplant. for each 8,000 hab. they are occupied 2 hours/ operating/shift for the waters plant and similar for that of solid wastes. It has not been put any chemical biocide neither machines, all is biological and natural. If we combine such waters microplants with those of solid wastes, the recovered resources are greater, paying very rapid the investments to be established micro and industries of the to recycling integrative and of promotion .....

According to noted what is the ecological tax, national average, it is of about $1.20/m^3. The operation costs average of treatment plants conventional in the scale of 50,000 hab. they are of about $1.00/m^3, our microplant costs about $0.30/m^3, but furthermore it help to create 5 employment in the utilization than what recovers , generate income instead of spending on transferring the pollution problems.

Political and urban impact
A) To the immediate future is considered that the impact will be the total change of the transfer policies of the problems and loss of resources, making drainage and but drainage, collectors, interceptors, tanks, machines, alone plants aerobics of "high-tech" (?!), since will not be justified neither economic, nor technical, neither social nor environmentally to make it them, upon existing the solutions in situ, SUTRANE, and intercepting about origin, dual microplant, both recovering resources.

B) Upon counting the communities on the control of their huge resources that today are pulled, their self-sufficiency and thus independence will be much greater. Already the struggle to obtain it has reaffirmed the position of the community in defense of their resources and environment, and it will be but important to the future.

C) Upon having elements the community to see of a thoroughly different manner what to make with their thank resources to the conferences, visits and training in company of Xochicalli, their negotiation capacity was reinforced since never they could be brandished technical neither economic arguments against the technology that agreed to use.

D) the internal process of organization participation of the communities permits to support them in their decision. The local relationships, national and yet international recognitions of Xochicalli, they have had to of be used to defeat the political resistance derivative from the facts indicated before (inertia business preference by what is foreign) of part of authorities and technical. Result curious that after the visits to works from Xochicalli all the technical personnel are expressed surprised and related, though outline yet multiple bureaucratic requirements. Each community that achieves it permits that many other similar groups that they are waiting the results of their management to achieve the financing to their microplants and sutranes, reinforce sensibly their position, what is demonstrated with the number quickly growing of works being begun.

E) the initial project was born of the proposal of Xochicalli of integral managing of the basins, being adapted to each neighbourhood. However the original design is to take advantage all the today existing exits, one by one or a few together, to each side of the contaminated basin, avoiding marginal collectors, tanks, siphons, pumping, etc., etc. commonly all the drainage of the bordering colonies to basins, as well as in many other sites, unload without treatment to the riverbed.

They are being proposing a series of macroplants on the part of private companies of great political and economic power, same that would handle the grant and would build all the necessary works against a collection moved to all the population. as I cited before, today it exists in our country a call " ecological tax" that gravel the residual water exhausts in base to their biochemistry demand of oxygen (BDO) and to the total discontinued solids (TSS). A bulk estimate fixes the average amount at country level in about the $1.20/m^3. To give an idea than what means, it is almost the double than what costs the m^3 of drinking water piped in Mexico. Back from so high cost, according to the cited CNA, it is the interest of the fact that all us "we convince" of the convenience to try the water, thus avoiding the payment of so high imposed. Also upon going paying it goes forming a fund to impel the treatment.

The problems begin upon knowing that said payment enters the treasury of the federation, dependent of the secretariat of estate and public credit, the one which redistributes money collected to any departure of any thing in any part, without nobody knows when arrive to the required site, even though it be paying.

Impact of the works

A) Is very difficult to specify the motives by those which the people recaptures the interest by their environment, certainly in part being a cultural cause in the interior of the country, in part upon observing the decrease of the quality of life of their accordant children advances the pollution, compared with the one which several of the greats had. But emphasizes by virtue of the struggle that they have followed during years to achieve the construction of the microplant, knowingly of the fact that their environment will be benefited very little in this first. Stage since dozen colonies and water towns up of their accession are now pulling their drainage and garbage to the riverbed, what them arrives today and them will follow affecting during several years. However they go taken conscience of the fact that it is economic contribution, historical if is wanted, sought with Xochicalli and other groups to obtain it a structural change, permanent, with respect to the new culture of the water (and at the same time ancestral, since our forebears it had by a form of deity), in the abusive consumption as well as to mess it and to pull it.

B) The impact that intends the work with the urban area is that of, to the time of decontaminate and to protect the environment, to permit count on resources to improve the urban image as well as the productivity, thanks to the recovery of: water, nutriments, energy and resources micro -industrializables. This will be achieved through the installation of plant nurseries and in the future greenhouses in the federal zone concessioned, as well as with the sowing of courtyard that have between house and house, in all the cases taking advantage the water and fertilizing recovered through the microplant. Below they are listed the plants to use.

Impact on the health

Almost 40 of our dangerous diseases have to do with the water, causing high illness and mortality in the world. their suffering and cure means million of dollars and hours - man/day of lost, thousands of hospitals and clinic beds, etc. we see table 1 of water related diseases.

Table 1: Diseases related to the water and/or the sewer.

	Disease	leaves of the man	enters to the man
diseases transmission by water ingestion	collar	h	o
	tifoidea	h,o	o
	leptospirosis	o,h	per, o
	giardiasis	h	o
	amibiasis	h	o
	infectious hepatitis	h	o
diseases by contact with water	mange	c	c
	sepsis dermal	c	c
	peep	c	c
	leprosy n	(?)	?
	louse and typhus	p	louse bite
	tracoma	c	c
	conjuntivitis	c	c
	bacilar disentery	h	o
	salmonelosis	h	o
	diarrhea enteroviral	h	o
	paratifoidea	h	o
	ascariasis	h	o
	tricocefalos	h	o
	trichinosis	h	o
	ankylostoma (lombr.)	h	o, per
	fungosis several	c	c
diseases of base in water	esquistosomiasis ur.	o	per
	esquistosomiasis rect.	h	per
	dracunculosis filaria	c	o
vector related with water	yellow fever	p	p mosquitoe
	fastidiousness water	p	p mosquito
	fastidiousness hemoragico	p	p mosquitoe
	fever of the nilo	p	p mosquito
	arbovirus encefalitid.	p	p mosquito
	bancroftion filariasis	p	p mosquito
	malaria, malaria	p	p mosquito
	oncocersiasis	p	p mosquito
diseases by fecal wastes	dream sickness	p	p tse tse
	woms necato	h	per
	clonoquiasis	h	fish
	difilobotriasis	h	fish
	fascilopsiasis	h	fish

symbology.- h=fecal wastes, o=oral, u=urinal; per=through skin, c=skin; p=prick; n=nose.

As is universal solvent, furthermore today we contaminate it gravely with toxic residues upon unloading rejected waters you domesticate, cattle and industrial, by liquid lixiviates and superficial deposit runoffs of garbage (open and burials "sanitary", to see annex 1), of fertilizers and chemical biocides, by thermoelectric (above all the nuclear), etc.

Because of this we outline our treatment proposals and, by virtue of the fact that in our houses we mess it mainly with our excretes, about 85 % than what we eat, of resources recovery, from a house through the SUTRANE until the dual plants in which exist drainage and can be able to do microplants (high urban density zones, historical, etc.). To evaluate the quality of the effluents of our microplants, are annexed analysis practiced by several public and private institutions that are cited forward. The effluents of our systems satisfy totally the Mexican official water procedures (NOM) in type DII, DIII and DIV, that is to say, from for recreational use and of flora and fauna conservation, until for industrial use.

Of they see the efficiency of pollutants removal:

A. - Microplant of the Ibero-American university, campus gulf - center in populates, in operation trying 3.25 LPs from September of 1991. Analysis practiced to comply with the normative regulation (CNA and SEDESOL) by Microquima, S.C., and LACCIA laboratories, S.A. de C.V., both recognized officially by the CNA.

B. - Treatment plant of the autonomous university Chapingo (includes three residence units) in Texcoco, Mexico, in operation trying 8.25 LPs in his 1st stage, from March of 1993. Analysis practiced by the state water commission and reparation of the government of the state of Mexico and by the Industrial Ecology Laboratory, S.A. de C.V., both recognized officially by the CNA. this plant yet it does not integrate neither its greenhouse, filters nor terminal systems.

In either case the facilities practically they do not use energy, you scheme neither chemical to achieve the following numbers:

Table 2: Removal efficiency.

parameter removal	efficiency (%)
coliformes total (nmp/100 ml)	92.66
biochemistry demand of oxygenate	90.43
chemistry demand of oxygenate	85.52
total solid solved	85 80

Note: in other parameters also exist substantial reductions that permit their operation within the NOM (to see annex).

Nevertheless what is favourable that it results our system according to the cited analysis, not always they will be the same numbers, depending whether the drainage is black or combined, of the toxic industrial residues that contains, of biocides (the treatment is biological), of the inffluent , etc. however of the international experience of similar systems managing have been obtained similar results (Germany, Holland, San Diego, NASA), being reliable, versatile, inexpensive and productive.

Exist parameters that for us are not adapted to indicate good treatment and quality of the water. Such is the case of the BCD: if we introduced fish to the effluent that is shown in the analysis, will increase of new together with several other parameters, depending on the type, load and if it is mono or policultive. Our systems remove upon transforming and caring, channeling where and as we wish the quantity of organizational matter, depends on the use that we give to it. the digesters that we use care and improve, upon transforming them, the types of nutriments that feed it; it can receive animal and rotten wastes with accounts bacterian of patogens very high and to transform them into foods, even protein unicellular. below we see a table of the national academy of sciences of Washington, USA ., on analysis in effluents of a type not settler of anaerobic digester (not as those which we have in the microplant, neither of so wide detention time as the differentiated that we give to it, as for example to the sediments, multi-year, in them):

Table 3: Destruction of germs for the fecal dregs digestion.

germ	temperature (°C)	time (days)	% of mortality
poliovirus	35	2	98.5
salmonella sp	22 - 37	6 - 20	82 - 96
salmonella tifosa	22 - 37	6	99
mycobacterium tuberculosis	30	-	100
ascaris lumbricoide	29	15	90
parasite eggs	30	10	100

there are similar results of ONU, GTZ (West Germany), CEMAT(Guatemala) and other institutions.

Replicability of the project

A) Appropriation level.

Black waters. The microplant seeks be a model to repeat all over the communities that today unload to the basins, substituting collectors, intercepting and trying the black waters you domesticate separated of the industrialists and/or of services, letting them equipment to recycle to surcharges of aqulfers, green zones irrigation, floriculture, etc. yet there can potabilisize without large investments. Already they were indicated other data about as achieving the participation from the project until the operation, and thus the technological appropriation for each group interested in making - to learn - to handle their microplant.

Domestic solid wastes. Of similar manner, is envisaged the integration of a processing microplant of these the one which wastes, previous not -mixture, classification and/or separation to optimize the process, permit to use the organic for enhance the obtained fertilizers from the waters phase, as well as the inorganic not infected - contagious neither dangerous for their recycling in microindustries of plastic, paper, carton, glass and metals.

The appropriation levels permit from the retorts total as in the SUTRANES, until the future participation of some of the trained in the construction - training - operation of other microplants in foreign communities.

B) Does not depend on waiting that the community has clarity concerning that to make, the " felt need", since this masked totally by the alternatives ignorance that them permit the participation, as is the usual case of the conventional treatment plants, in which is sought to darken the process so that it will be business of a few, so much in the project, work and the operation - reinstatement - maintenance. To act from the planning participate encourages the interest but not assures it, therefore it is very important count on it scaleable prototypes in all sense, remarked demonstration of the viability practices and economic sought; also it is basic the transfer process through the training. We have had to develop an alternative educational methodology to transfer alternative technologies, illustrated in annexes: "ERCA method", "training in avalanche" and " appropriation process to reach the quality of community life".

Finally it must be exercised the process of through contributions to the community revolving funds, through an also alternative accounting.

1.2.6 Conclusions

The project represents a step but in the new technologies that treat and at the same time recover the goods that today we pull ("wastes"!) and with those which we contaminate, and very particular and trascendentally, an important potential support (depending on we to achieve it improving it and adapting permanently, through "multiobjective programs of action investigation" so that the communities could handle their resources, preserve and restore their environment to accede, promote and spread the sustainable development or ecodevelopment, in opposition to the expensive technology, dependent and predator, seeking be converted into ecological -productive and solidary that improve and assure our quality of present and future life, as well as to all the habitat and their resident.

We end indicating the gold rules to satisfy within programs of ecodevelopment, that they should include:

- maximization of use of local resources.
- minimization of use of external resources.
- complexity (planned diversity, permitted, recaptured and enhance, known or not - yet being investigated).
- not pollution neither present nor future depredation.
- echeloned and multiple use of conventional and alternative resources.
- integration from the water captation until the micro-agro -transformation.
- viable practical and economically.
- car - constructible - operable and - gestionable.
- recovery and reimbursement to productive product cycles today underemployed and/or rejected.
- observation, investigation with peasant, indigenous, etc., great respect to recapture and articulate vernacular knowledge with scientific, ancestral and modern, own and foreign......

that is framed with three conditionant for the participation:

to know to criticize
to investigate to propose
to agree to act

It is fundamental to achieve to articulate and potencializar various answers (as are all our community resources) to the problematic complex of the reality, alone thus we will solve it.

1.2.7 Some considerations, our thinking and experience about the slow dissemination of the alternative sustainable wwts.

1) Actually position of technological failure defence: instead we affirm that it is impossible to violate the laws of physics:

   Nothing is created nor destroyed, only changes.
   Each time one add a step to a physical process -and everyones are-, augment the entropy.

2) Technological inertia. The mega- and macro-systems are- augment the entropy.
3) Preference on foreign 1st. World technologies, independent of if them operate or not.
4) Novelty which implicates risk ("is better bad but known than good but unknown") and possibilities of criticism, what does not happen when are used poorly operating conventional systems because ever is possible to say: "The system is wright, what happens is that we don't have the money to operate it".
5) Wrong regulations, specialized and only thought in decontaminate the water, not if the pollution in is augmented through concentration (thanks to the non-adequate treated sludges) and dispersion (thanks to oxidized gases) of the pollutants that originally are in the waste water, paradoxically thanks to the resources that they have.
6) Enhancing a focus too academic or too empirical, which should be compensated.
7) Corruption, which promotes the more expensive and dependent systems against the opposite.
8) Very low capacity of publicity, promotion and dissemination, against conventional systems sold through big enterprises.
9) Thanks to very few systems installed, the validation and alternatives -the adequation- is not enough in every conditions, sites, water qualities etc.
10) Usually approaches -and so designed- not as system to recover resources, but only "to treat", emphasizing it, so don't speaking on to make business with such resources but with the systems by itself, through a sale.
11) Poor knowledge on the importance in the potential users: authorities, golf field operators, food producers, etc.
12) Scarcity of funds to finance alternative systems, thanks to many of the dormer points, and ignorance and/or inexperience on the way to get finance, national but particular international (examples: EG, World Bank, FMO Bank etc.).
13) Status of "competition" against conventional more expensive systems, with a lot of mathematical formulae and expertise "demonstration of it failure" (see point 1).
14) Scarcity of a sustainable offer: projectors, calculists, builders -engineers and hand labourists- etc, in general.
15) System diversity, thanks to an enormous variation in alternatives: sites, size, climate, materials, quality of waste water, regulations, etc., which add time to response, complexity, inefficiency and costs.
16) We can not compete against international money bound to some special technology if we have not the same cost and quantity of money.

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1.3 Small Scale Systems for wastewater treatment and compost toilets in the countryside & in towns, *S.A. Leeflang.*

Stichting De Twaalf Ambachten, "The Twelve Trades",
Centre for Alternative Technology ,
Mezenlaan 2, 5285 HB Boxtel,
The Netherlands,
Tel.: +31 411 672621,
Fax: +31 411 672854.

1.3.1 Introduction

In 1977 our foundation 'De Twaalf Ambachten' ('The Twelve Trades') started a centre for alternative techniques in Boxtel, in the southern part of the Netherlands. In this centre we experiment a lot in the field of heating (heating walls, tile stoves for wood burning and gas combustion), semi-underground building and grassroof construction, durable energy, watersaving, -purification and -recycling systems, as well as tools and implements. Once in a fortnight on Saturday we show interested visitors around and from time to time we organize a course on sewerage replacing techniques, such as helophytefilters, compost toilets etc.

What did we develop in the last 16 years on the subject of water saving and purification? We started experimenting with compost toilets. It took several years to develop our so called compact compost toilet ("CC") which we consider more and more as an environmentally safe and hygienic alternative for the water spilling flush toilet. And what is even more important: when using a compost toilet we only need a small planted sand filter (a reedbed filter, also called a helophyte filter) for purifying our grey household water, mixed with the liquids coming from the compost toilet.

This is the principal base for a small scale system, which could be used in big cities. Per inhabitant we only need approximately one square meter of plantbedfilter. We now experiment with light weight filters for use on roofs and balconies of which we expect approximately the same purifying capacity at at weight of only one third of the sandbed filter.

It is important to know, that plantbedfilters require an area three times as large, when we want to maintain our flush toilet and that such a water consuming toilet also requires a septic tank of minimal 1.000 liters as well. It may be clear, that in most circumstances, when living in a city, one cannot find enough space for such a waste water treatment system. Therefore it is necessary to realise that the sewerage systems, that are applied in most big cities in the industrialized world, are still in use, because small alternative and ecological sound systems have not yet been available or known.
In the last few years it has become apparant that the combination of sewerage pipes under road decks and heavy traffic in the streets becomes an unbearable financial burden due to rising maintenance costs. Even in a rich country like Holland the bancruptcy of some of our big cities is predicted, due to the rising costs of sewerage and rainwater-saving systems. We have entered this critical stage, because the high velocity drainage occurring after heavy rainfalls causes a lot of water pollution, as well as groundwater losses in higher parts and floods in lower parts of the country: a combination of polluting and spilling which cannot be tolerated any longer for legal reasons and financial consequences.

Let me emphasize that it is not oldfashioned nor primitive to say goodbye to the flush toilet and the sewerage system that belongs to it.

1.3.2 Water saving

In an average household of about 4 to 5 persons we save about 60.000 liters of water (in most cases pure drinking water) when we exchange the flush toilet for a compost toilet.

Under certain circumstances it is possible to save even more water when we replace our current showerhead as used in most of the bathrooms.

About ten years ago we discovered an American water saving showerhead, saving about 40 percent in comparison with a normal shower head. The construction was complicated and expensive, so we looked for another way of constructing this device, using as much as possible existing parts currently used by plumbers. The result was a very simple product that did the job and even better: it saved 60 percent of the water normally used, provided there is enough waterpression of at least 2,5 bar. It is important to say that not only this showerhead is simple to manufacture, but that it is also very durable because it is assembled of copper and brass parts, lasting a lifetime! This cannot be said of the many water saving products made out of plastics.

1.3.3 Compost toilet

The best way of water saving in our household is of course avoid-ing the application of a flush toilet. We have, therefore, spent many years in examining existing composting toilets and trying to construct better ones - that is: cheaper ones and systems that do not require much maintenance. Two types of composttoilets resulted from these many years of experimenting: a flat type for placing on a existing floor and a round type which disappears for 50 centimeters under the floor, producing a step-free toilet and looking more or less like a flush toilet. This type enables us also to construct a hole in the floor for use in countries where (like in the far east and parts of Africa) squatting is the normal defaecating posture.

Both types show a revolving container, about 1.70 meter long, in which a second compartment is used for composting and a first compartment to catch the freshly dropped faeces, which are captured in minced straw particles, with which we fill this part of the container for three quarters. The rotating principle of this container is very important in our view as it lets the mass to get aerated. This happens even twice when turning the container: the contents of the first compartment falls into an interspace between the first and second compartment and then it drops in the composting chamber as soon as the container has been turned back into its neutral position.

It is important to emphasize that the form of the partitions is bent in a S-shape. Only if the partitions are formed in a right shape, the faecal mass will move and fall down, as it is a rather sticky mass...

Another thing of importance for the right functioning of our compact compost toilet is the presence of a filter tube near the bottom of the first compartment. This is meant as a drainpipe for the urine liquids. The filter tube discharges the liquids to the greywater wastepipe or waste-water tank and when the water in this tank is free of floating particles (due to the partitions made in this tank) we can pump it to a reedbed filter for purification.

Thanks to this drainage of urin liquids the standard type of the "CC" with a width of 1 meter can be used as long as eight to twelve months before turning and emptying the compost compartment becomes necessary. In our Dutch climate with quite the same temperatures as the British average this is enough for getting the faecal mass composted.

Finally we have to deal with the odour of a compost toilet. In our compost toilets we use a small electric ventilator of 12 Volts DC, 1 Watt. These ventilators have a collector free , electronically switched motor and even the cheapest mass manufactured ones, normally applied in computers, are perfect for ventilating our compost toilet. They make no noise (normally operated at half speed) and they consume very little electricity: a small battery connected to a small solar panel will do. We also applied what we call our 'sun chimney': a black painted tube or pipe, placed in a transparant, airthight case made out of silicon-glued glass strips or a plexiglass tube. At the top end of the vent pipe we use a case of thin metal or nylon netting to avoid flies entering the toilet system. As long as we can maintain a certain underpressure in the toilet container flies will not appear.

1.3.4 What materials?

We can make a compact compost toilet container with either water resistant plywood, to be treated with epoxy-resin, or with stainless steel, or welded polyethylene plates or ferro cement. For mass production polyethylene seems the best choice, especially when one has these materials at one's disposal in a recycled and thus cheaper form.

In our centre we often use ferro cement, making tanks, filtercontainers and composting toilets. It is the strongest and most durable of the materials for your money, even when using modern glas fibre netting as strengthening agent in stead of iron netting.

■ *The cheapest compost toilet*
The simplest and cheapest compost toilet is a plastic 60 liter cask or barrel of the type used everywhere in the chemical industry. In order to make a practical toilet out of it we add:

1. a ready-made wooden seat with lid, to be screwed to the rim of the barrel;
2. an equalizing rod, preferably made out of stainless steel, in order to avoid 'faecal piramides' trying to build up under the toilet seat;
3. an electrical ventilator and ventilation pipe, connected to the barrel;
4. a plastic filtertube, connected to the bottom of the barrel, e.g. a piece of garden hose, used as a drainpipe.

The barrel which is slightly too high to sit on, can be placed in a hole in the floor, with a depth of 10 centimeter or in a deep hole in the ground (for squatting position).

The best way is to take a clean barrel (with its own filtertube) and exchange this for the first barrel when this is full; its weight then being around 30 kilogram (faecal mass, minced straw and toilet paper). We advocate this kind of exchange of barrels or containers as part of a municipal service in the near furture, when new city quarters are built and no money is left for expensive sewerage.

1.3.5 Heavy & light weight filters

The cheapest plant bed filter is a hole in the ground, covered inside with a sheet of plastic, installed with a drainpipe in a bed of crunched shells or pieces of lime stone and filled up with very fine sand, eventually with a small or even large contents of iron (which helps to eliminate phosphates by binding). In this sandbody we plant reedplants (with hollow roots bringing oxygen in the filterbed) or other marsh-plants, like bamboo or papyrus, depen-ding the climate and zone. On top we lay the pressure-pipes-with-holes distributing the wastewater. This kind of plantbedfilters give a very good result and generally speaking 92 to 97 % of most of the organic and anorganic pollution is eliminated. The plantbed filter is self regenerating: each new growing season the roots get new offshoots, making many new holes in the toplayer of sand for the waste-water to penetrate whitout a chance of clogging, which always happens in a sandfilter without plants.

Our newest experiments concern light weight filters in which as a filtermaterial sand is replaced by mineral wool. By applying these filters we can reduce the weight with more than 60 %. The first indications obtained, are that these filters (with a horizontal meandering and step by step downward waterflow), can do a good filtering job and will do this sufficiently when the effluent is kept for some time in a pond in which waterplants can reduce residues of nitrate and phosphate. In the big cities the construction and maintenance of such ponds as a living element of parcs (which in their turn can contribute greatly to the health of the citizens) could be another important task of the municipality.

 Mezenlaan 2, 5282 HB Boxtel , the Netherlands. Telephone: +31-411-672621; fax: +31-411-672854.
A new professional publication, dealing with do-it-yourself systems for water purification and recycling, as well as construction of compost toilets will appear in English translation in the first half of 1997. Work title : Alternatives for Sewerage. Price, postpaid/airmail US $ 75 cash or international money order or US $ 82 when payed by cheque.*
** Dutch title Rioolvervangende Technieken.*

1.4 Institutional Requirements for Appropriate Wastewater Treatment Systems, *J. Frijns & M. Jansen, IHS*[1].

IHS,
P.O.Box 1935, 3000 BX,
Rotterdam, The Netherlands,
Tel: +31 10 4021560,
Fax: +31 10 4045671,
E-mail: jos.frijns@ihs.nl / marc.jansen@ihs.nl

1.4.1 Unsustainable sewerage and treatment methods

It goes without saying that the uncontrolled release of domestic wastewater in the urban areas of the developing countries causes severe pollution problems and negative health effects. This asks for proper solutions, which appear to be not readily available. The magic answer is not yet there. Besides, straightforward and uniform solutions do not exist, each location requires a specific approach.

In this paper there perhaps will be more questions than answers forwarded. In our view, the problem with sewerage and wastewater treatment is either the use of an inappropriate technology system and/or a poor institutional arrangement for the management of the system (Box 1).

Box 1: General reasons for problems

1. lack of adequate institutional arrangements
   - little attention for treatment
   - no long term planning & lack of coordination
   - lack of involvement community & private sector
   - inadequate resource mobilisation
2. low technical sustainability of the waste handling systems
   - inappropriate and costly methods of collection and treatment
   - high tech, large scale, capital intensive, centralised treatment
   - irrational, water-borne, high cost, extensive sewer collection system

■ *Inadequate management*

It are the municipal authorities who have the task to provide sanitation services. So far, however, local authorities have been unable to provide the service to an adequate level. Institutions dealing with sanitation often lack a service orientation and are not customent oriented.

[1] Jos Frijns and Marc Jansen are lecturers of the Department of Urban Environmental Management at the Institute for Housing and Urban Development Studies in Rotterdam Both have experience with sanitation and wastewater treatment in developing countries IHS is an international oriented institute that offers education, training, research and advisory services on urban development in order to contribute to human resource and institutional development

The institutional problems related with water and sanitation have to do with:
- proliferation of agencies
- fragmentation of their efforts
- inadequate powers at local authority level
- engineer oriented, top down approach
- lack of comprehensive technical and organisational policies
- lack of finances, etc.

As the service should be paid for by the users, they should provide the service that people want and are willing to pay for. However, local governments have often difficulties in an adequate mobilisation of sufficient financial resources. The lack of resources not only results from a general lack of funds at the municipal authority level, but also from an inadequate municipal tax collection and problems with cost recovery.

Box 1: General reasons for problems

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■ *Inappropriate technologies*

It is more and more being realised that conventional wastewater treatment methods, developed in Western countries and transferred to developing countries, are rather inappropriate. Conventional treatment is generally centralised (off-site), water-borne, large-scale, capital intensive and high-tech. It's inappropriateness relates to the involved high costs, the often insufficient pathogen removal, the limited reuse possibilities, the release of large amounts of contaminated sludge, and the required knowledge and institutional support for operation and maintenance. Over the years, many treatment systems have been developing rapidly achieving higher efficiencies with reduced financial and environmental burdens. It is thus nowadays not accurate to refer to Western systems as all being conventional.

However, the conventional concept for treatment has as an important precondition the transfer of the wastewater to the facility, thus requiring an extensive sewer system for collection. It is especially this sewer system which forms a major constraint for its adoption. Its exceptionally high cost makes it out of reach for most cities in developing countries (Cairncross & Feachem, 1993). Other limitations are listed in Box 2.

Box 2: The limitations of conventional sewer systems

1. Cost: Very high capital construction cost and annual exploitation costs.

2. Water use. To transport wastes along the pipes large volumes of water are required. Households have to have individual water supply connection

3. Construction: Complex technology requiring careful and skilled construction and thus skilled people.

4. Sewer-laying: To dig large trenches in straight lines through (squatter) settlements will often necessitate the demolition of houses. It requires large excavations

5. Phasing: Sewer systems need to be implemented along with water and housing. It is difficult for sewerage systems to be developed incrementally

6. Blockage: Prone to blockage if large objects such as solid waste are fed into them. And an irregular water supply may lead to clogging of the sewers.

7. Leakage: Leakage is very hard to detect. Yet, it occurs frequently, causing groundwater pollution.

8. Irrational use of resources: Irrational from the point of view of sensible utilisation of resources, dilution of waste with clean water for transport, after which it will be separated again in a treatment facility at high cost.

End-of-pipe solutions tend to be imposed on the total system. In such a way a pre-occupation with a certain wastewater treatment technique may lead to the development of sewer systems where a (partial) on-site system would possibly have been more appropriate.

1.4.2 Available treatment alternatives

What then are suitable alternative methods for water-borne sanitation and wastewater treatment? In any case, it requires an appropriate technology which is affordable (note the difference with low-cost), simple, and aimed at reuse of valuable resources (see Box 3). A very important requirement, also in relation to reuse options, is that the technology has to be effective in hygienic perspective. Most of the, in Western countries, used treatment technologies were not developed with the aim of pathogen removal. The spreaad of diseases is, however, the most severe problem of domestic wastewater in developing countries.

Over the years, several interesting technology alternatives have been developed and tested, which overcome the main problems of conventional systems and apply to a large extent to the mentioned criteria.

Several modifications of the sewer system are currently being used which have lower costs, reduced water requirement, minimal excavations, and less maintenance requirements. Among the modifications is the shallow sewerage system, a network of small-diameter pipes laid in shallow trenches with small inspection chambers, usually in the backyards and alleys of settlements (Vines & Reed, 1990).

Box 3: Criteria for Appropriate Sanitation Technologies

- Technically Sound
  - effective & efficient
  - flexible
  - simple in O&M
  - process stability & long life span
- Environmentally Sound
  - integrated: no diffusion of pollution to other compartments
  - hygienically safe
  - limited environmental impact (pollution & resources)
  - aimed at recovery & reuse
- Affordable
  - cost-effective & low cost (construction, infrastructure, O&M)
  - financially feasible
  - using local materials & low energy requirements
- Socially & Culturally Acceptable
  - meeting needs
  - local labour-intensive
  - convenient for user

Alternative treatment technologies are developed as well which can be served by these relatively low-cost collection systems. Certain water-borne treatment systems could be applied at a smaller scale, i.e., community on-site, in which the wastewater at a residential area of limited size is collected in a small-bore sewer and treated at the site of the concerning community at some proper location. This could be an alternative as well to conventional on-site sanitation systems which frequently suffer from a rather low treatment efficiency.

Anaerobic treatment using the UASB-system is one of the promising technologies for application at this level (Lettinga et al, 1993). Effective treatment and some recovery of biogas is achievable with limited maintenance and sludge disposal. Post-treatment for effective pathogen removal, however, is still required. The method most suitable for tropical countries for pathogen removal is stabilisation ponds. The main disadvantage of ponds is that they take up a lot of space. In urban areas where land is scarce or very expensive, ponds may have to be rejected. However, great savings in space can be achieved by incorporating anaerobic pre-treatment, thus the application of a relatively small stabilisation pond at the site of the community as a post-treatment method could become feasible. It should be born in mind that often one of the best investments a municipality can make is to buy land for ponds on the outskirts of the urban area. Moreover, such 'simple' sanitation programmes can be upgraded in a planned sequence of incremental improvements, whenever the socio-economic status allows this.

Even more alternative technologies exist, albeit none of them perfect. The question remains, however, why then are these technologies not (yet) widely applied?

1.4.3 Conditions for the implementation of alternative methods

It is important to note that the application of interesting alternative wastewater treatment methods not only is determined by the technology it self. In practice, the choice of sanitation technology will depend on various local circumstances as well (Box 4).

The dissemination of technology depends on the socio-economic setting in which the technology is introduced. Although an alternative sanitation can be indeed less costly per capita than conventional sewerage, many do have on-site (investment) components, requiring efforts and resources from the residents. The question of affordability remains, depending on site conditions. Acceptability could be a problem as alternative sanitation is seen in certain areas as second-rate options to conventional sewerage by professionals and residents.

If we have a closer look to the proposed alternatives for wastewater treatment, it might become apparent that although a method in itself is appropriate from a technological point of view the local setting does not allow a successful introduction. In other words, the institutional framework is often not in place to create local conditions favourable for the alternative treatment methods. This very much explains the difficulties with technology dissemination. The engineer tends to overlook the importance of an effective institutional setting which can support the application of the developed technology. A poor or incomplete institutional framework prevents satisfactory performance of any sanitation technology, even when they are technically properly designed and constructed.

The institutional setting determines as well the optimal scale of operation/application of the selected treatment technology.

Box 4: Local conditions determining the choice of sanitation technology

1. Physical environment
climatologic conditions & hydrogeology
soil conditions & topography

2. Socio-cultural aspects
defaecating habits & attitude towards excreta handling
urbanisation pattern (population density)

3. Infra-structural aspects
the present water supply system & stormwater drainage system
local and individual building standards

4. Financial capabilities of the target group
affordability & willingness to pay
residual value of, and market for, processed wastewater

5. Management requirements for operation and maintenance
institutional support
skills & training

6. Institutional framework
planning and policy
organisational setting
human & financial resources

1.4.4 Institutional requirements for successful support of appropriate methods

One of the important lessons of the UN Water and Sanitation Decade is the emphasis on 'making systems work' instead of the mere provision of facilities. Institutions need to be developed in response to the tasks and activities as required to keep the chosen wastewater treatment system operating and effective. Sanitation projects require an institutional framework that allocates authority and responsibility for planning, construction, operation and maintenance, and monitoring of the schemes.

Can simple on-site systems be handled within the individual family and neighbourhood, by contrast a high-tech wastewater processing plant will require trained people, procedures, risk management and elaborate cost recovery mechanisms. The more elaborate collective system applied, the more elaborate the institutional support should be. Large and complex programmes tend to be demanding in their technical as well as their managerial components, and require the commitment of different levels of government.

Box 5: The institutional framework provided by local government

- comprehensive policy for the sector
- planning and management
- agencies with adequate capacity for implementation
- appropriate regulatory legislation and capacity to enforce
- financing and revenue generation
- market oriented (both for the service and waste products)
- operation and maintenance of the system
- provision of training
- quality control and monitoring of pollution levels
- providing infrastructural facilities
- coordination with other policy areas (health, housing, settlement planning, etc.)

Therefore, each chosen system should be analysed as to the required tasks connected to its sustainable functioning, which in turn should provide a strong indication of its ultimate feasibility. Thus, local government should ensure a proper institutional setting, consisting of planning, coordination, resource mobilization, etc. (see Box 5).

A good organisational structure is required, based on a steady, long-term government support, and a clear national policy supporting the sector. At city level, a sectoral agency is needed to provide technical support. Coordination with other policy areas is an important task, ensuring no fragmentation among a variety of institutions (no overlapping responsibilities). Stable, autonomous institutions have to be set up, which can secure sufficient funds and competent staff (opportunities for training and salary increase).

■ *Local government as facilitator*

Many municipal authorities appear not to be able to provide the required service to an adequate level. Too often no adequate division and allocation of responsibilities at community, municipal or central government level results in malfunctioning and deterioration of the wastewater systems. It is therefore recommended, that the role of local government should change from direct intervention towards the enabling of public and private institutions to deliver services. The role of local authorities could become more one of a facilitator (see Box 6).

One of the important tasks remaining the responsibility of the public sector will be the coordination between interrelated subsectors. The interlinkages and integrated approaches between sewerage, solid waste systems, water supply, and drainage, should be kept in mind. Any solution to be successful will have to be positioned within a multi-variant environment.

Box 6: New role of local government

- facilitator
allocating authority & responsibility
supervision & monitoring

- partnership approach
private sector
community participation

- overall coordination
linking user - engineer
part of urban environmental management

■ *Partnership approach*

In facilitating the provision of wastewater treatment conditions have to be created that enables the involvement of local partners. The institutional arrangements should be geared to shared responsibility (decision making at the lowest level) and service delivery institutions that are responsive and accountable to users. This thus implies local partnership to ensure effective community participation and a greater role for the private sector (Bartone, 1995). A partnership approach, however, also needs an appropriate institutional framework, which clearly lays out the roles and responsibilities of each party.

With private sector involvement it is aimed to enhance efficiency, lower cost, and mobilise resources. Competition, accountability and transparency should be the basis for successful privatisation. In Mexico, for example, municipalities are granting concessions to the private sector to build and operate wastewater treatment plants. However, in general private sector involvement is illusory, and their willingness to invest in this sector is limited. Moreover, involvement of the private sector is in no way a substitute for a proper overall institutional setting. Public sector capacity even has to be strengthened to regulate private sector participation, e.g., to establish standards to guide private contractors, to assess performance indicators, etc.

The user plays a key role, which is not always realised by the sanitation specialists. Community participation could be solicited in planning, financing, construction, use and maintenance. On-site sanitation schemes may be completely or partly managed and financed by the users themselves. The role of government organisations may be important nonetheless, for example through public information campaigns, or to assist technically (desludging services). Effective communication between the users and the local officials is a prerequisite.

For example, the application of shallow sewerage in high density areas requires extensive promotion of community awareness at the planning stage, together with house-to-house and physical surveys, and good quality control during construction. An additional problem is that such on-site systems have to be considered as private goods. How then is inspection and maintenance on private land to be organised? In case of the so-called condominial sewerage system in Brazil this is done by the users themselves, which works satisfactory. Water boards supervise the building and provide information on maintenance to the users (UNCHS, 1986).

In case of off-site systems community participation may be equally important but rather difficult to achieve. Experiences with for example solid waste management learned that involvement of the community is essential for its success. Likewise in wastewater treatment participation of the people is needed, e.g., to prevent release of toxic waste substances in the sewer, to assist in site selection, for financial contribution, to achieve environmental and health improvement, etc. But how can involvement for wastewater treatment be established? The user generally is not interested at all in the processing part. Treatment has low priority, as by then waste is already out of sight. The problem is that the benefits of treatment do not really accrue to those who generate the waste. In fact their real priority is to move the wastewater out of their own front yard. One has to be very careful about pre-supposing considerable knowledge, as perhaps done too often by sanitation technologists, about wastewater systems among the user groups. For them it disappears underground, period.

Once people have been connected they tend to become reluctant in paying their dues. Defaulting is very common. Switching off is physically not possible; other sanctions do generally not work. Who indeed can disconnect them? A mechanism of charge collection by a related authority, e.g., the water supply company, could be an effective answer for cost recovery, especially when sanctions can be applied through disconnecting the water supply.

As in a partnership with the private sector, the involvement of the community requires as well a proper institutional setting to ensure its success.

1.4.5 Conclusions

Although several interesting appropriate wastewater treatment technologies have been developed over the years, the magic answer does not seem to be there yet. Besides, appropriate solutions will differ anyhow with the site conditions where they have to be introduced. Moreover, successful implementation very much depends on the institutional framework that creates the conditions for its operation and management.

The development of even more innovative appropriate technologies, for example aimed at full reuse opportunities, does not change this prerequisite and is thus as such no guarantee for successful dissemination.

All too often the developments are technology driven, after which conditions for the required institutional framework have to be established. It could prove to be a better strategy to start from the existing institutional setting, see how this can be improved, and then look at which technology fits best.

As said, it is the often poor or incomplete institutional framework that causes sanitation programmes to fail. Adequate institutional arrangements are needed that incorporate long term planning, coordination, and resource mobilisation. A partnership approach, involving the community and private sector, could assist local authorities.

The role of local authorities changes to one of a facilitator, allocating authority and responsibilities. This new role does not imply a reduced involvement of local government but a different one. In fact, a proper institutional framework is the more important. It should provide for a link between the users and the engineers. For a sustainable system a design and a management framework is needed that knows how to deal with the technical processing underground as well as the part above ground dealt with by the user.

Local governments have to take up their responsibility in the overall coordination of urban environmental management and ensure wastewater treatment service as part of this. Recent urban environmental management experiences stress an integrated approach, in which professional and sectoral barriers have to be removed. Indeed, this is not an easy task.

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1.5 Resource-Recovery Wastewater Treatments with Biological Systems, *W.J. Jewell*

Department of Agricultural and Biological Engineering,
202 Riley-Robb Hall,
Cornell University,
Ithaca, New York 14853 USA,
Tel: +1 607-255-4533,
Fax: +1 607-255-4080,
E-mail: wjj1@cornell.edu

1.5.1 Introduction

More than a billion dollars per year of energy is consumed or wasted by conventional sewage treatment processes in the U.S. Furthermore common aerobic treatment alternatives generate large quantities of sludge that costs hundreds of millions of dollars for final disposal. Increasing restrictions on discharge of wastes emphasize the need to recover wasted resources at lower capital and energy costs. Over two decades of R & D at Cornell University has focused on technologies that have the potential to recover valuable products from sewage while producing clean water at costs lower than conventional alternatives. This paper summarizes a comprehensive pilot documentation of this technology.

1.5.2 Background

An anaerobic attached microbial film process, referred to as anaerobic attached film expanded bed (AAFEB), followed by a hydroponic treatment process using plants, referred to as nutrient film technique (NFT) were tested at large pilot scale. Both technologies have been under development for over two decades and a half, but they have not been scaled-up beyond laboratory scale. This is the first study that enabled these technologies to be examined on a long-term basis.

The anaerobic digestion process, or conversion of organic matter in the absence of oxygen, is a useful process because it converts organic matter to carbon dioxide and methane. This gas, often referred to as biogas, can be used as a substitute natural gas since over half the volume is methane or “natural gas”. The use of an anaerobic process to treat domestic sewage has the potential of converting all organic matter to substitute natural gas while leaving dissolved plant fertilizer in the treated water. These nutrients are undesirable in many applications since they cause eutrophication of waters, or undesirable accelerated aging that results from addition of plant nutrients to surface waters. The use of a simple plant system to treat partially purified wastes from anaerobic systems would enable plant nutrients to be removed, thus converting nutrients into a useful form. This plant matter could also be a valuable by-product. Thus the combined application of an anaerobic process along with a hydroponic plant system provides the basis for a concept that we refer to as "resource recovery wastewater treatment". All materials contained in domestic sewage can theoretically be converted to useful by-products in such a system. The total value of substitute natural gas produced by such a system could exceed $100,000 per year when applied to sewage generated by 10,000 people.

Unfortunately, anaerobic microorganisms involved in the methanogenesis of complicated organic matter are, in general, not considered to be applicable to cold and dilute domestic sewage. The limiting step, the formation of methane from acidified fermented organic matter, is one of the slowest steps in the microbial world. Since these biological processes slow down with decreasing temperatures, this means that the bacteria will be growing slowly in water that is affected by low temperatures.

To develop an anaerobic process capable of higher rates of conversion in smaller reactors, researchers at Cornell University developed a process, beginning in the mid-1970's, to concentrate bacteria and make them easier to handle in an attached film. By carefully choosing small and low-density inert particles to encourage microbial film attachment, the quantity of microorganisms per unit volume of reactor can be increased substantially over processes that utilize bacteria in a suspended and less well-controlled form. This enables a larger mass of slow-growing bacteria to be accumulated for more difficult applications, such as anaerobic conversion of organic matter at low temperatures. Numerous studies have been conducted with the AAFEB and it has been shown to be capable of efficient conversion of organic matter even at low temperatures and under simulated real-world conditions.

The general attitude in the U.S. for use of anaerobic systems in sewage treatment is that it has a role as a pretreatment system, primarily for organic industrial wastes, but it cannot be used for domestic sewage treatment. Our study has indicated that this is not true, the anaerobic process can meet secondary effluent standards. There are, however, several limitations to this process that must be considered, and these were examined in this study. The first is dissolved gases that are generated by the anaerobic fermentation processÑhydrogen sulfide and methane. The second is the fine black suspended solids that are created in an anaerobic environment that may be difficult to settle from wastewater. Both of these anaerobic treatment characteristics need to be considered for aesthetics and discharge permit considerations.

The hypothesized resource recovery wastewater treatment system also included management of primary sludge. Raw wastewater was fed directly to the anaerobic expanded bed. Sludge accumulated in this unit and gradually stabilize and was removed from the system as a partially stabilized sludge.

Many plant-based wastewater treatment processes are now being developed; however, few, if any, have been shown to be viable alternatives for year-round treatment in all geographical areas. Constructed wetlands and other alternatives usually limit plant species to marginal-value plants such as water hyacinths or other wetland plants. The plant treatment system introduced by our group at Cornell University, the Nutrient Film Technique, offers the potential of using all plants including ornamental terrestrial plants, trees, as well as aquatic plants. In addition it is the simplest form of hydroponics in that no media is required once the root mass is established on an impermeable surface.

The NFT was developed in England for commercial plant production purposes. Our adaptation for wastewater treatment is based on the observation that all plants tested appeared to grow well in the system, thus making all plants candidates for waste treatment including those that have significant value. In addition, nutrient stresses that plants experience in other growth media appear to be a less severe constraint when grown in the NFT system. In other words, the balance between major nutrients and trace elements may be less critical in an NFT than in another growth format.

Since the NFT is created by using lined channels and wastewater is managed similar to other unit processes, the accountability of materials is easily achieved. Thus regulatory concerns with the fate of materials can be addressed more easily in these constructed systems than in natural systems.

1.5.3 Study Appraoch

A schematic of the hypothesized system is illustrated in Figure 1. This pilot began operation in 1986 and remained in continuous operation for over four years. Wastewater was diverted from the local sewage treatment plant and utilized in an "as received" form. No attempt was made to divert wastewater at any time. This meant that the feed wastewater contained intermittent large doses of sewage sludge and toxic materials that ultimately caused a fish kill in the conventional plant effluent during the test period.

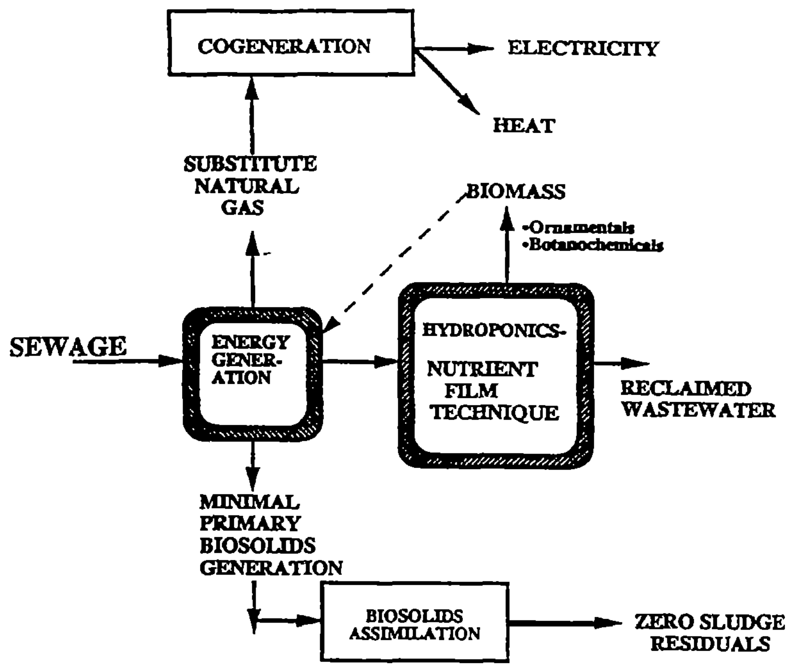

Figure 1: Schematic of concepts involved with "Resource-recovery wastewater treatment"

The temperature of the wastewater varied from 7 °C to 28 °C, and little attempt was made to control temperature throughout the system. The wastewater was not heated in the anaerobic treatment process nor in the NFT channels. The air temperature was maintained during the winter months at approximately 4 °C (45 °F) in the greenhouse to maintain the biological community.

Wastewater flows to the system were varied from 2 to 44 m^3/d (up to 10,000 gal/d). The goal of the test program was to test a set of parameters for a long enough period of time to document system removal and conversion capability for all major pollutants. This database was intended to document variables controlling pollutant removal, and to provide a quantitative predictive capability. After each test condition was verified by numerous analyses, conditions were changed. For the most part, each steady test condition lasted four to five weeks. For the expanded bed, a total of more than 30 steady operating conditions were obtained, and a total of more than 80 conditions were documented with the hydroponic system.

The greatest limitation in considering both technologies examined here is the lack of long-term operation of the biological system under "real world" conditions. Anaerobic biological films may take a year or more to develop mature films. Little is known regarding this development in cold sewage. Aquatic plant systems are an even larger problem since multiple seasons are necessary to document nutrient cycles during plant growth and decay. This four-year study represents one of the longest tests of both technologies.

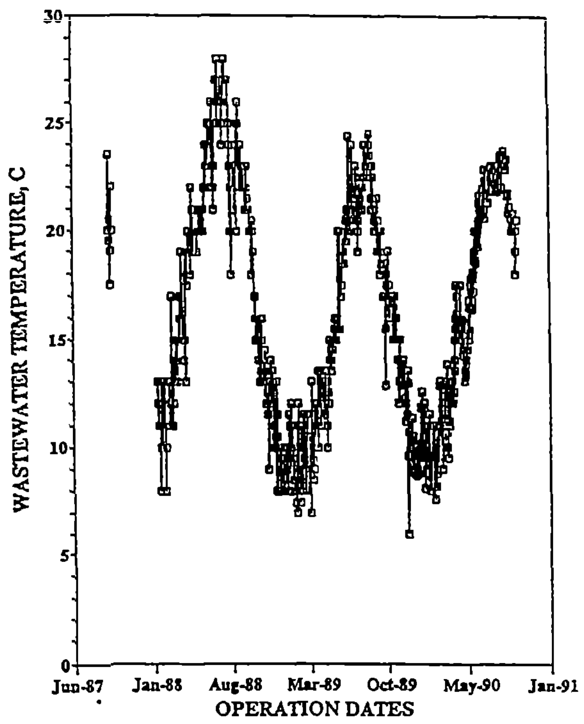

Figure 2: Pilot system influent wastewater temperatures observed in the 52 month study using the domestic sewage of Ithaca, New York

1.5.4 Results

The proposed resource recovery wastewater treatment system performed in an outstanding manner with a minimum amount of energy consumed to achieve a maximum quality effluent throughout the four-year study. Previous efforts have been severely limited because most have operated small systems for a limited number of plant cycles; and the resulting biological community that was established may not have represented equilibrium conditions. In this study plants were grown continuously for four years of growth and decay, and equilibrium conditions can be considered to have been approximated.

Feed sewage temperatures ranged from 6°C to 28°C (see Fig. 2) and other characteristics were as variable (Table 1). Ithaca's sewage is dilute and highly variable because of groundwater and stormwater infiltration.

Table 1: Summary of domestic sewage characteristics measured in feed of the Cornell University 52 month pilot study at Ithaca New York

Parameter		High	Low	Average
Study period		10-01-86	08-31-90	
Influent temperature	(°C)	28	6	
Influent flow	(s/d)	44.1	2 0	
Influent pH		9.5	5 8	7 2
Chemical Oxygen Demand				
COD total	(mg/l)	1421.4	103.4	319.0
COD soluble	(mg/l)	1099.5	21.2	173.5
Biological Oxygen Demand				
BOD total	(mg/l)	679.0	43.4	107.8
BOD soluble	(mg/l)	58.7	34.7	48.3
Volatile fatty acid	(mg/l)	85.0	0.0	15.3
Nitrogen				
total Kjeldahl	(mg/l)	38 5	12.9	22.2
ammonia	(mg/l)	19.3	7.6	13 6
nitrate	(mg/l)	4 0	0.0	0.6
nitrite	(mg/l)	7.5	0 0	0.2
Phosporus				
total	(mg/l)	10.1	0 6	3.9
ortho	(mg/l)	36.6	0 0	3 1
Solids				
suspended solids	(mg/l)	764.0	30.0	114.6
volatile suspended solids	(mg/l)	600.0	11 5	85 0
Sulfur				
sulfate sulfur	(mg/l)	18.2	0.0	12.7
sulfide sulfur	(mg/l)	8.0	0.0	1.6

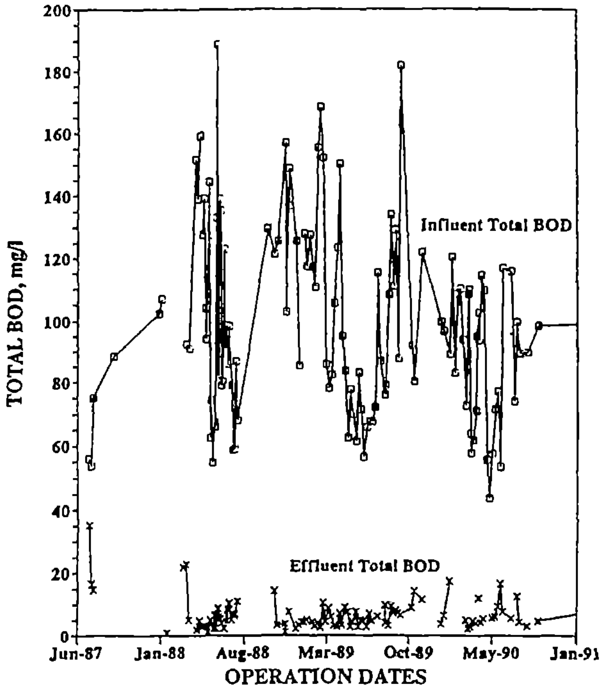

Figure 3: Pilot system influent and effluent total five day BOD concentrations measured during 52 month study.

An overview of influent and effluent water quality for the entire treatment period is shown in Fig. 3 and 4. Even though the experimental program was designed to document process limits and failure, it is obvious that the effluent quality remained high throughout all testing.

The total system was shown to be capable of producing amongst the highest quality water ever observed with natural, biological, microbial and plant-based systems. At low loading rates, effluent BOD and suspended solids concentrations were reduced to less than 5 mg/l under almost all test conditions. Also at low loading rates, dissolved plant nutrients were reduced to undetectable levels as was the case with the indicator organisms, fecal coliforms, thus eliminating the need for the final disinfection unit process required in many treatment systems.

The anaerobic attached film expanded bed (AAFEB) performed in an excellent manner for longer than three years of continuous operation. Very little attention was required to manage the bacteria and to keep the bed in continuous operation. No new media was added to the system for the duration of the study.

The AAFEB was applied in a two-stage mode with the first stage being utilized as a sludge accumulation/digestion unit. Suspended solids were separated and gradually passed through the expanded bed and accumulated as a digested sludge blanket on top of the first bed. Hydraulic retention times in this unit were often two to four hours. The accumulated sludge was periodically wasted and carefully monitored to determine total waste sludge production. Effluent from the first stage flowed by gravity into a smaller second-stage bed which was intended to reduce the remaining organic matter to a secondary-or-better quality level.

Accumulation of attached biofilm in the first stage (AAFEB-1) and the second stage (AAFEB-2) is shown in Fig. 5. First stage biofilm concentration approach 30 g VS/l bed are typical of values measured in laboratory studies; but the second stage value of 20 g/l bed were low. This reflects the fact that acetate utilization did not occur in the first stage, but acetate served as the main substrate in the second stage.

The first stage anaerobic bioreactor acted as a clarifier, and as a sludge storage and stabilization step. At warmer temperatures effluent, SS averaged less than 20 mg/l, but increasing viscosity caused effluent SS to approach 40 mg/l in the first stage of the expanded bed (Figure 6 and 7).

Low temperatures and low substrate concentrations are especially challenging conditions for methanogenic systems. Further complications are also presented by the presence of about 13 mg/l of sulfate-sulfur. The fate of BOD_5 is shown in Figure 8 and 9. The average total BOD_5 of 108 mg/l was reduced to 48 mg/l, on average, but many values were below 30 mg/l.

An estimation of sulfate reduction showed that most of the sulfates were reduced to sulfides in the first stage anaerobic reactor. Half of the effluent BOD was caused by sulfide oxidation, and the remaining 24 mg/l was almost 100% acetate. Thus, the average carbonaceous BOD in the effluent was 24 mg/l throughout this study.

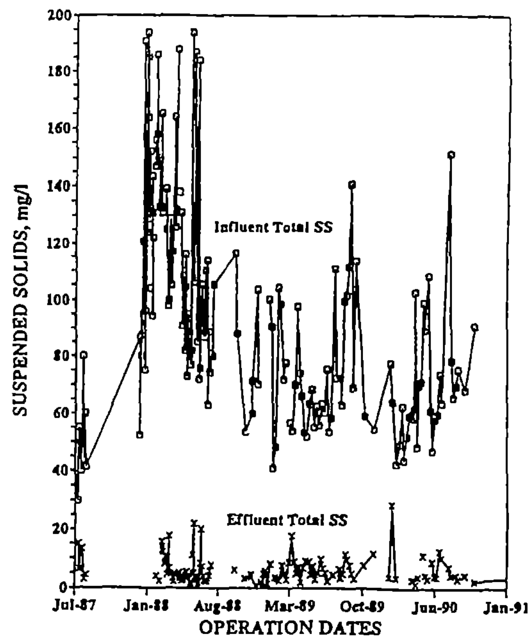

Figure 4: Pilot system influent and effluent total suspended solids concentrations measured during 52 month study.

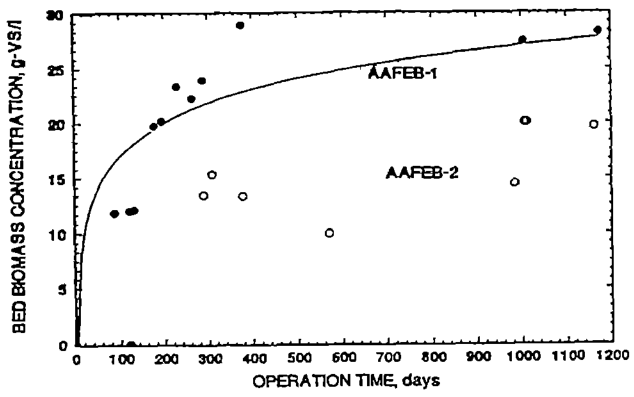

Figure 5: Biomass concentrations in the expanded bed of the first (AAFEB-1) and second stage (AAFEB-2) anaerobic reactors; the support attachment media was Celite diatomaceous earth..

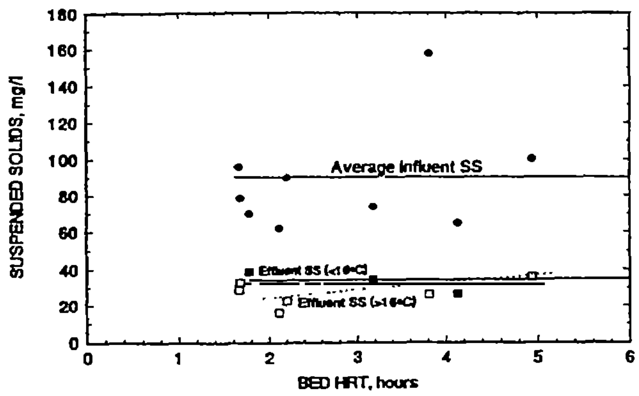

Figure 6: Average influent and effluent suspended solids concentrations of the first stage AAFEB reactors as a function of the bed hydraulic retention time at temperatures above and below 16°C.

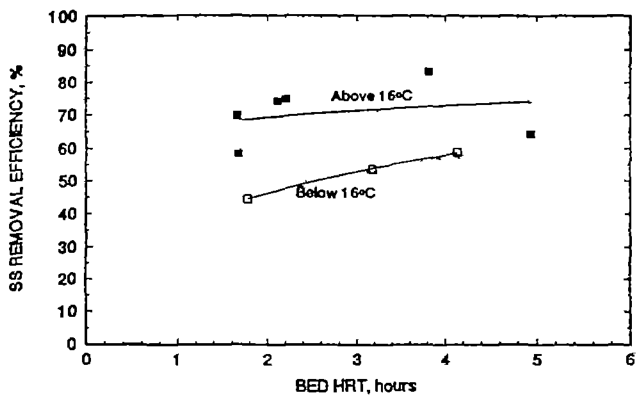

Figure 7: First stage AAFEB reactor average suspended solids removal efficiency as a function of the bed hydraulic retention time at temperatures above and below 16°C.

Efficiency of most processes were directly related to the loading and hydraulic retention time but not to temperature. For hydraulic retention times of one hour in the first stage and four to five hours in the second stage, this anaerobic process reduced the organic BOD (volatile fatty acids) to less than 20 mg/l, with a resulting total BOD of less than 40 mg/l including organic suspended solids, dissolved sulfides and methane. Sulfides accounted for about half of the anaerobic effluent BOD. Thus the anaerobic process was shown to be capable of meeting secondary effluent providing that hydrogen sulfide and suspended solids were managed.

The main temperature effect was observed in suspended solids management in the anaerobic process with suspended solids removal efficiency of 80% when the temperature was greater than 16°C. At lower temperatures the increased viscosity of the water was such that the fine solids that originated in the sludge blanket and from the attached film were carried out of the system. Efficiency was reduced to 60% with effluent suspended solids often around 40 mg/l at wastewater temperatures ranging from 7° to 12°C.

The sludge stabilization aspect of the on-line system was found to be highly successful with the total amount of sludge produced in over three years of operation equaling less than 40% of a conventional aerobic secondary biological treatment plant and even less than that produced by a primary treatment plant that included anaerobic digestion. Thus the sludge management aspect of the AAFEB offers significant system simplification and sludge reduction.

Because the process separated hydrolysis and acidification in the first stage and depended on the second stage for methanogenic activities, very little temperature effect was also observed on sludge stabilization. Short hydraulic retention times used in the first-stage system were acceptable because sludge was still maintained at a long enough solids retention time to achieve efficient conversion.

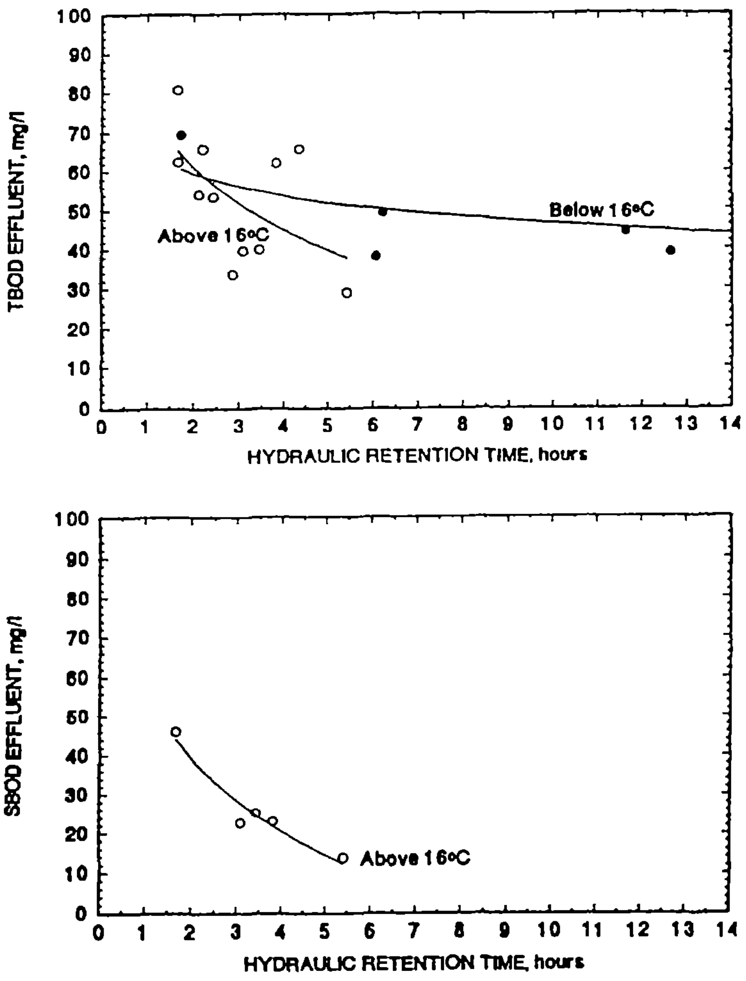

Figure 8: Average AAFEB reactor system effluent total (Top graph) and soluble (bottom graph) five day BOD as a function of the bed hydraulic retention time at temperatures above and below 16°C.

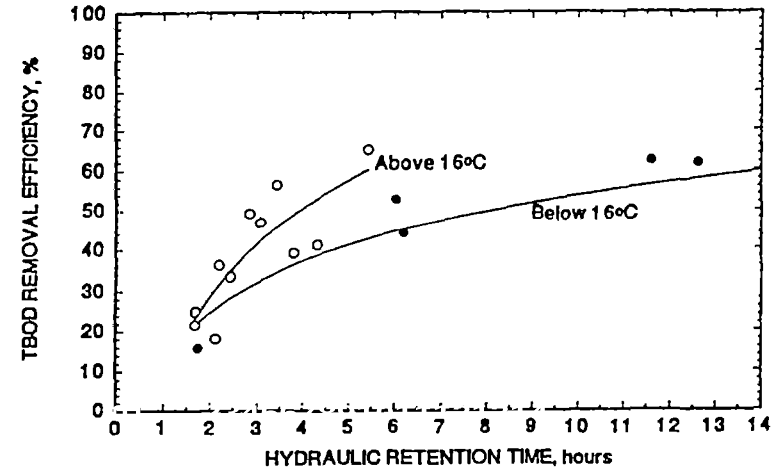

Figure 9: Average AAFEB reactor system total five day BOD removal as a function of the bed hydraulic retention time at temperatures above and below 16°C.

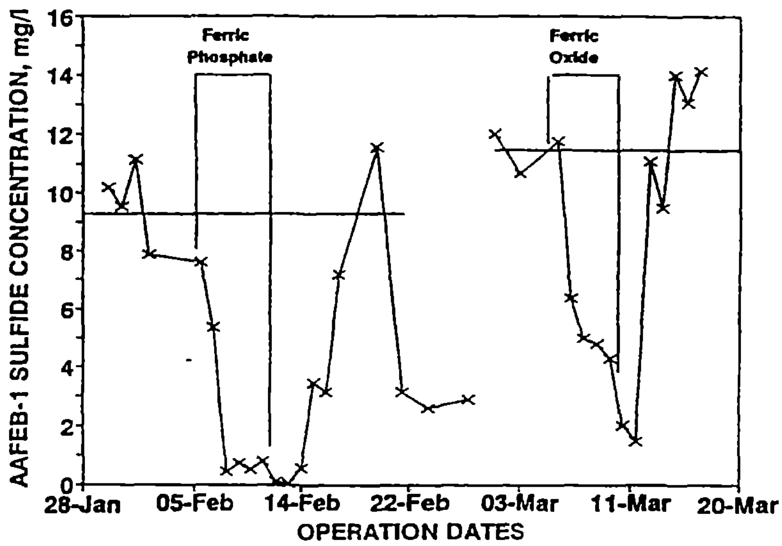

Figure 10: Chronological illustration of the effects of ferric phosphate and ferric oxide additions to the first stage AAFEB reactor sulfide-sulfur concentrations.

1.5.4.1 Sulfide Management

Sulfur containing compounds may generate offensive odors during anaerobic treatment, and as a result this characteristic can eliminate this treatment alternative. The most common cause of this problem occurs in methanogenic systems in the presence of sulfates. Sulfate reducing bacteria can use organic matter to reduce sulfates to hydrogen sulfide. Although there was no odor associated with the hydroponic system, higher sulfide concentrations may result in phyotoxic conditions as well as odors. For this reason a simple technique to lower sulfides in water was investigated.

Results from addition of insoluble metal salts to precipitate sulfide is shown in Figure 10. Stoichiometric amounts of ferric oxide and ferric phosphate were applied directly to the expanded beds and substantially decreased sulfide contents. Further development of this approach would involve recovery and recycle of the metal.

1.5.4.2 Biofilm Kinetic Comparisons

In order to confirm that the pilot facility developed mature biofilms, characteristic of those developed in earlier studies on synthetic substrates, samples from the pilot bed were removed and tested under well-defined laboratory conditions periodically over the pilot study life. Comparison of these pilot subsamples to other data shown in Figure 11 confirms that the pilot systems had achieved biological capabilities similar to earlier studies that confirmed the potential for low temperature sewage treatment.

Definition of minimum organic conversion rates and efficiencies would provide a strong rationale to use anaerobic treatment processes for domestic sewage treatment. Data from a 2 year test of an anaerobic expanded bed treating an average of 40 mg/l of COD (Sucrose synthetic substrate) is shown in Figure 12. Over a broad range of temperatures and loadings, about 70% of this influent organic matter was degrading, thus emphasizing the potential for anaerobic treatment of cold and dilute substrates.

1.5.4.3 Nutrient Film Technique

NFT plants grew exceptionally prolific and were easy to manage excepting for their extreme height and health. The nutrient content of the cattails (which were the main plant used [*Typha glauca*]) contained three to four times the nitrogen content of wild varieties and reached heights exceeding four meters. Other plants such as wild iris were tested in small numbers and were found to also be ideal in this system. The wild iris, that averages half a meter in height, grew to greater than two meters in the NFT and remained green throughout the winter. The cattails turned brown and went into a dormant state during the winter phases.

Surprisingly, the efficiency of the NFT system was not severely affected by temperature or season. Effluent BOD and suspended solids were almost always less than 5 mg/l at lower hydraulic loading rates (less than 10 cm/d) or substantially better than conventional treatment processes (Figure 13, 14 and 15). A review of other aquatic plant systems indicates that the NFT is twice as efficient as many other plant systems since effluent quality in many other wetland systems was reported to produce effluent BOD and suspended solids of 10 mg/l or greater. Because of the large particle size of the NFT effluent suspended solids further reduction by a low-maintenance sand filter could easily be achieved.

1.5.4.4 Refractory Organic Matter Reduction

One interesting aspect of NFT treatment was the reduction in refractory organics, or COD not measured as BOD_5. Many wastewater treatment facilities that meet secondary organic standards of less than 30 mg/l BOD_5, still contain 50 to 100 mg/l of COD. High clarity NFT effluents often contained a total COD of less than 25 mg/l at low loading rates, thus suggesting capability to further reduce organic components in the effluent.

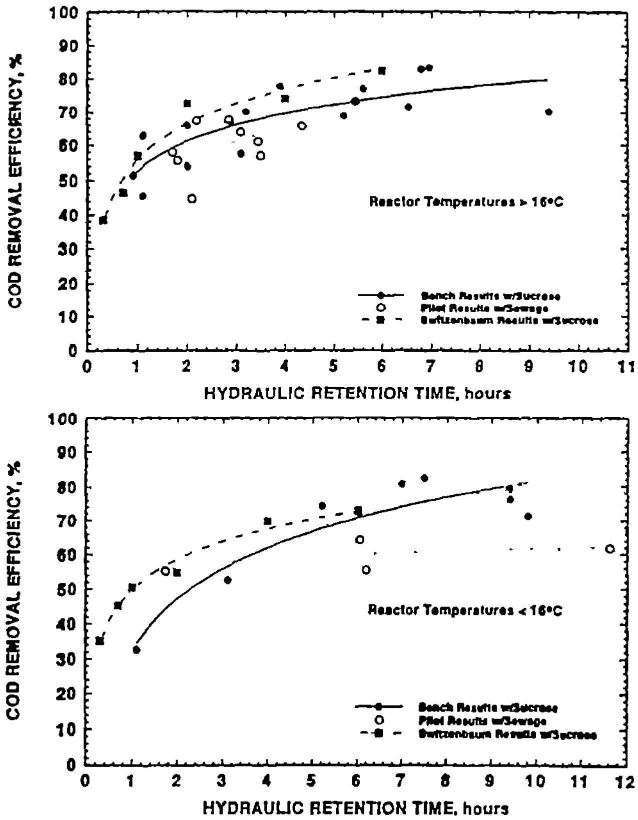

Figure 11: Comparison of bench scale, pilot scale, and Switzenbaum COD removal efficiency as a function of the bed hydraulic retention time at temperatures above (top graph) and below (bottum graph) 16°C.

1.5.4.5 Nutrient Management in NFT Systems

Efficient removal of nitrogen and phosphorus was attained at sewage loading rates less than 5 cm/d (Figure 16 to 18). A loading rate correlation was attained for these parameters and others showing a relatively linear relationship up to approximately 10 cm/d. At about 10 cm/d relatively inefficient nutrient removal was attained, but good BOD and suspended solids removal were achieved at much higher loading rates.

A considerable scatter in NFT nutrient removal data was expected because of the large number of variables included. However, it is interesting to note the high efficiencies of both nitrogen and phosphorus removals at lower loading rates. Even when constructed wetlands are loaded at 2 cm/d or less, neither nitrogen or phosphorus removal is very efficient, especially when the system operates at equilibrium. At a hydraulic loading rate of 2 cm/d, the ammonia/nitrogen and ortho-phosphorus concentrations approached zero, throughout the year, in the NFT system.

1.5.4.6 Indicator Organism Reduction

In all previous constructed wetlands work, disinfection was required because microbial reduction was not sufficient to meet regulatory requirements. Microbial reduction in the NFT system appeared to be loading rate dependent (Figure 20). At lower hydraulic loadings (less than 5 cm/d) disinfection may not be required.

Annual yields in the system were substantial with the cattail stalks generating 20 to 40 metric tons (dry) per hectare per year. The total biomass production of the root and stalks approached 100 metric tons per hectare per year on a dry matter basis. Practices to harvest maximum biomass were not identified in this effort.

An effort was made to document the fate of metals in the system and the quantity of humus generated in the root mass. One NFT unit that started with washed rhizomes of *Typha glauca* was monitored throughout the study. After the first year of plant growth, no net accumulation of material occurred indicating that the root zone was likely to be in equilibrium after the fourth year of operation. A total accumulated root depth of between 10 and 20 cm occurred in the system after the first year with dry matter accumulations of approximately 30 to 40 metric tons per hectare per year. The volume of rhizomes was fairly constant at approximately 70 l/m^2. The dry mass of rhizomes was about half the total mass in the root area. The humus or fine partially stabilized organic matter that could be washed off the roots on testing represented a highly stable material with an ash content of almost 70% of the dry matter. A review of the heavy metal content of the plants and humus showed that the large majority of the metals were contained in the humus. Cadmium appeared to be somewhat increased in the plants, but was six to ten times more concentrated in the organic humus in the root zone.

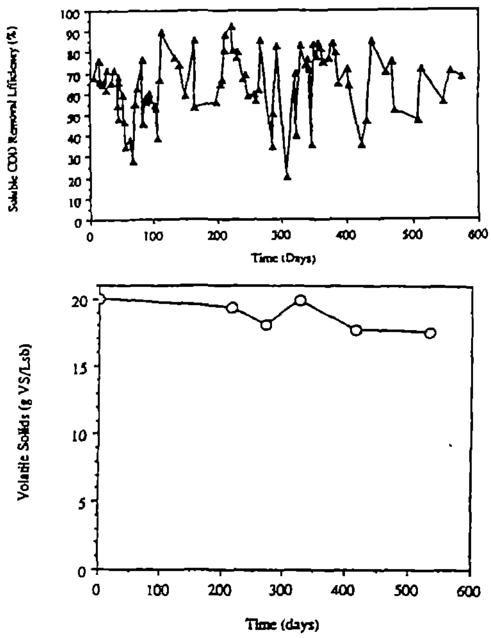

Figure 12: Soluble COD removal afficiency in low concentration feed runs treating chlorinated ethenes where the average influent COD was 40 mg/l, temperature ranged from 10°C to 20°C, and expanded bed hydraulic retention time varied from 3.3 to 30 hours (top graph); and fate of attached microbial film biomass in this 1.7 years of low concentration runs .

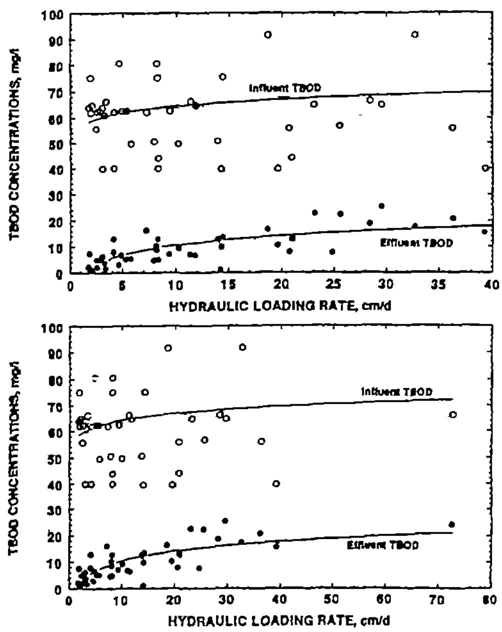

Figure 13: NFT system influent and effluent five day total BOD concentrations as function of hydraulic loading rate.

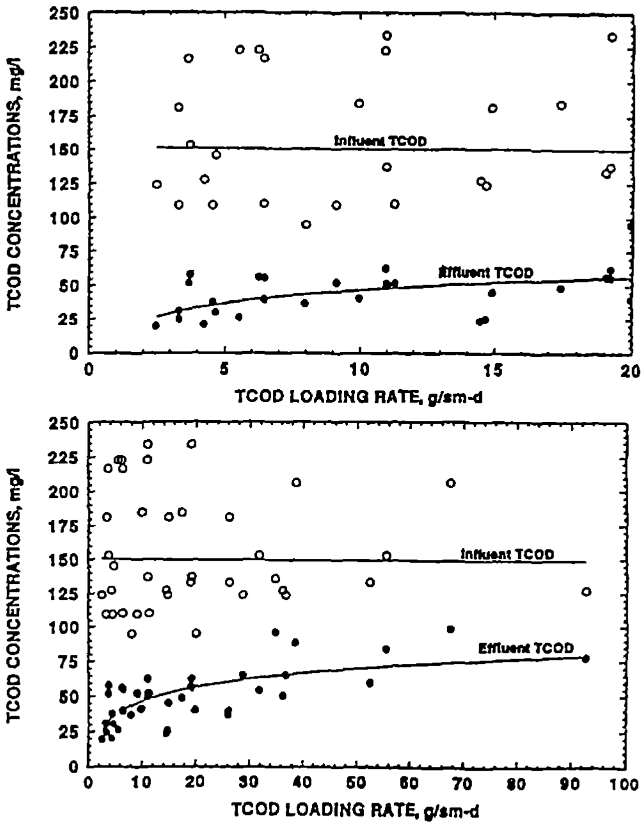

Figure 14: NFT system influent and effluent total COD concentrations as function of the TCOD loading rate.

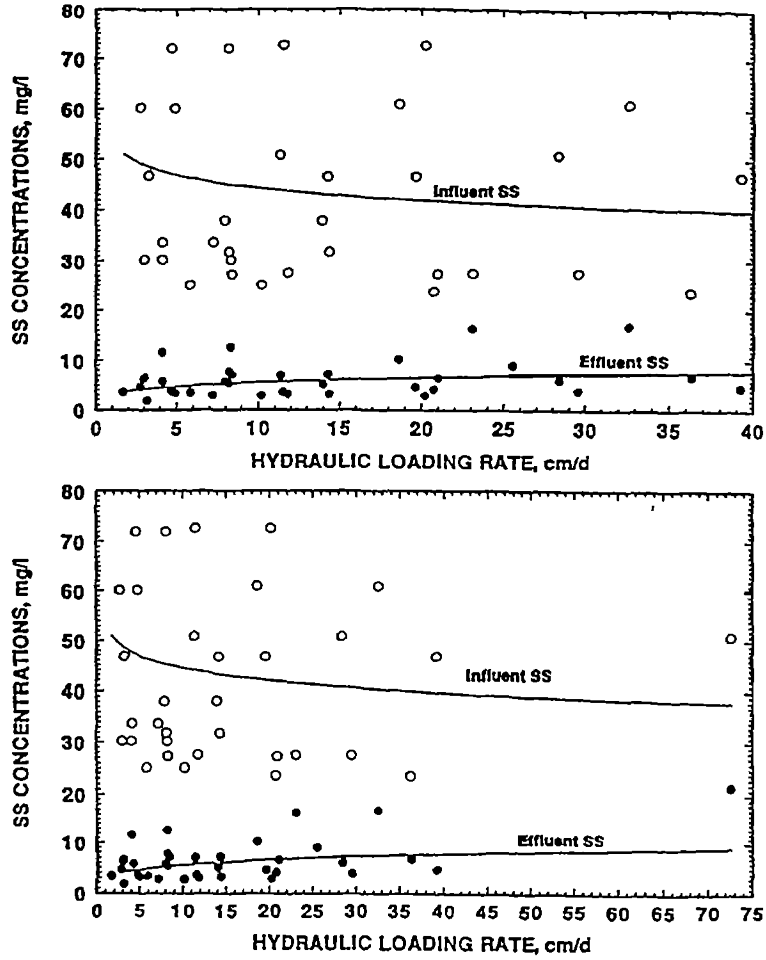

Figure 15: NFT system influent and effluent suspended solids concentrations as function of hydraulic loading rate.

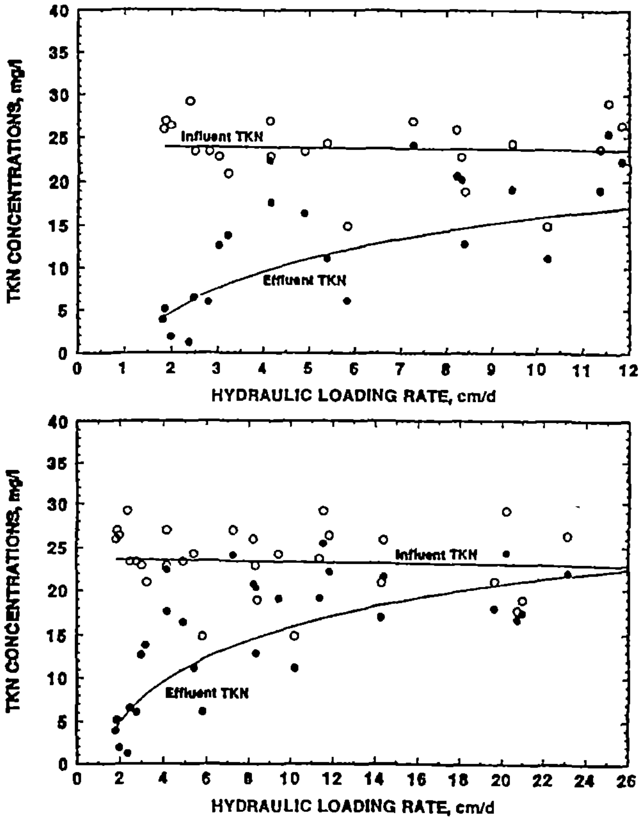

Figure 16: NFT system influent and effluent TKN concentrations as function of hydraulic loading rate.

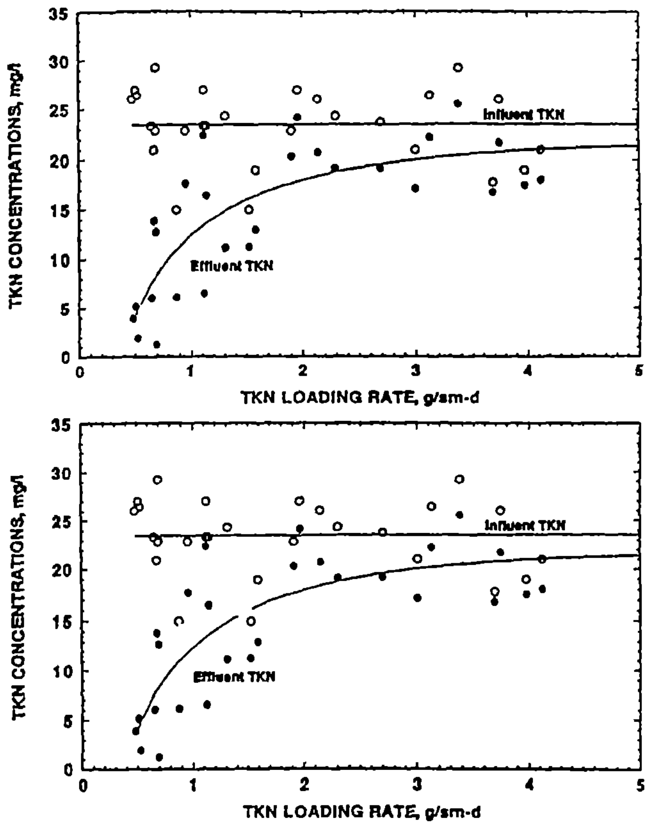

Figure 17: NFT system influent and effluent TKN concentrations as function of the TKN loading rate.

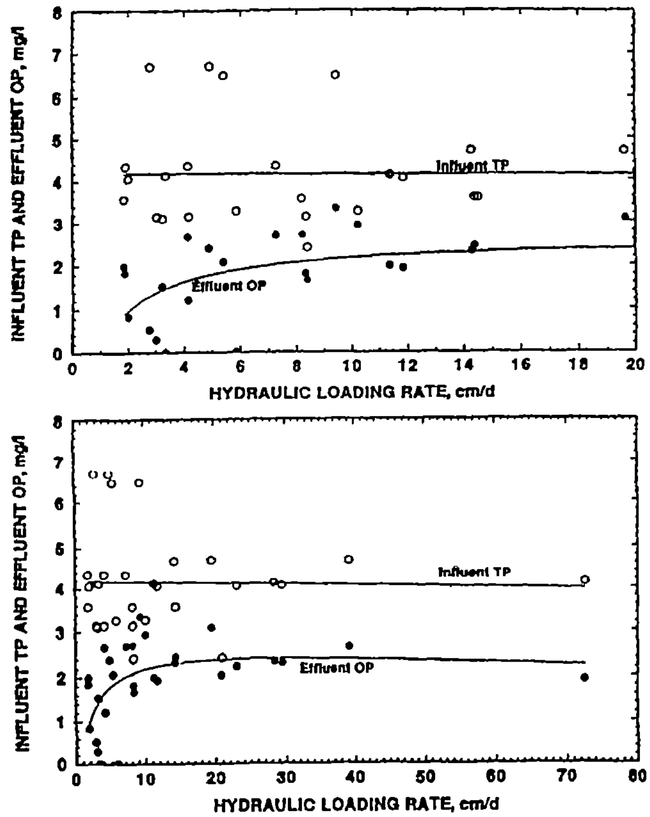

Figure 18: NFT system influent total phosphorus and effluent ortho phosphorus concentrations as function of hydraulic loading rate.

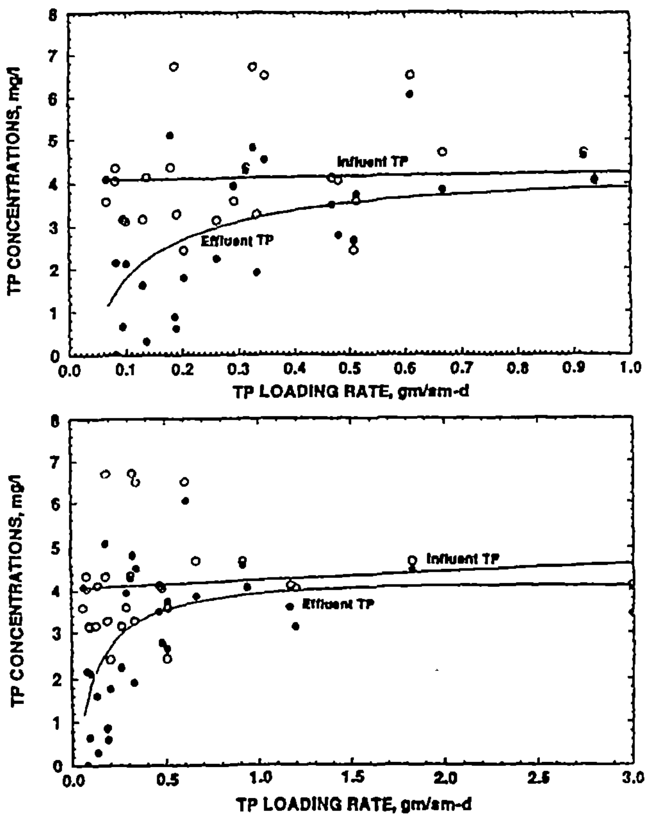

Figure 19: NFT system influent and effluent total phosphorus concentrations as function of the phosphorus loading rate.

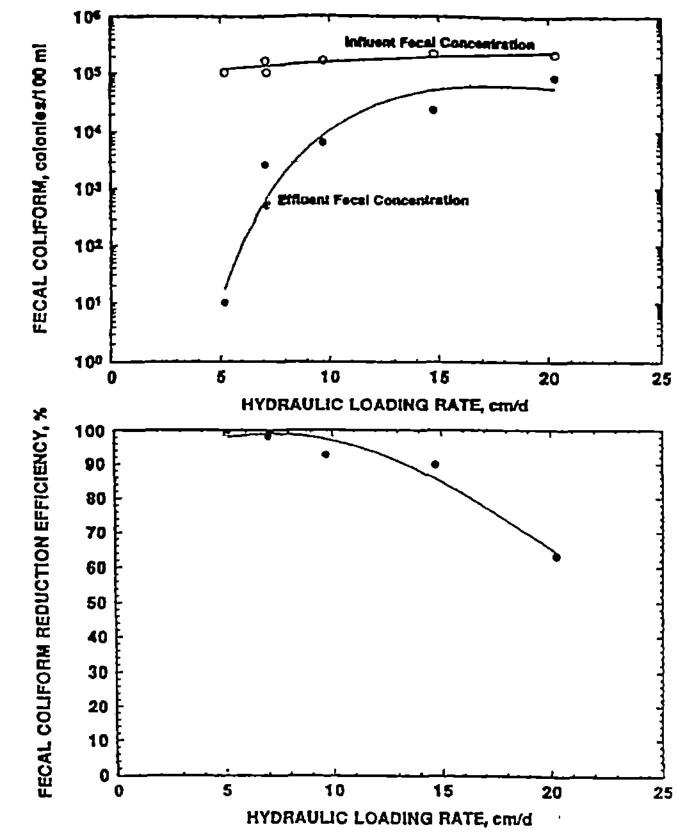

Figure 20: Average NFT reator system influent and effluent Fecal coliform concentrations (top graph) and removal efficiencies (bottum graph) as function of hydraulic loading rate.

1.5.5 Discussion and Conclusions

There are a number of ways that the resource recovery wastewater treatment system can be considered. The combined AAFEB and NFT system can be used to meet secondary effluent requirements with a minimum-size NFT system and perhaps without a greenhouse cover. The NFT system in the secondary treatment application for 10,000 people would be less than 2 ha in size. If nutrient removal aspects of the system are to be considered, the NFT must be enlarged to be between 10 and 20 ha depending on the nitrogen and phosphorous content of sewage.

Two technologies were combined in a long-term pilot-scale test program to determine the possibilities of minimizing the cost and complications of domestic sewage treatment while providing substitute natural gas and other valuable products. The attempt to incorporate technologies that minimize sludge production and maximize energy production and other by-products has been referred to here as "resource recovery wastewater treatment".

In this 52-month study, the microbial system was developed for over three years and the plant system was developed for over four years. The hypothesized system consists of direct anaerobic treatment of domestic sewage in a process referred to as the "anaerobic attached film expanded bed process" (AAFEB). This system was utilized to remove soluble organics and suspended solids and to stabilize primary sludge in the same process. Anaerobically treated wastewater was introduced to a second process, the hydroponic system referred to as the "nutrient film technique" (NFT). The NFT accumulates a microbial biodegradation community in the root area that enables adsorption and conversion of many pollutants contained in the wastewater from the anaerobic system.

The AAFEB has been under development since 1973 and the hydroponic NFT system was first applied as a sewage treatment process by a Cornell University team in 1978. This is the first scale-up of these two technologies and the first combined test.

Major characteristics of this test program include 1) the use of the anaerobic system for cold dilute sewage treatment, 2) a long-term sizable flow test program, and 3) the testing of a plant system in northern climates where relatively little information exists, especially over a period of time that enables the total biological system to reach equilibrium conditions.

In general, the hypothesized concept worked extremely well for the duration of the test program. A wide range of variables was imposed on the treatment system including temperature fluctuations, instantaneous sludge loadings in the feed, and toxic organics. Effluent quality remained consistently high with BOD and suspended solids less than 5 mg/l for much of the time. Soluble nitrogen and phosphorus concentrations were reduced to undetectable concentrations year-round under low loading conditions. Finally, at these low conditions it was found that indicator microorganisms (fecal coliform) could be reduced to less than that required in disinfected sewage effluent without the addition of disinfecting chemicals.

1.5.5.1 Study Output

This pilot study was intended to answer a number of fundamental questions about the use of new technologies for decreasing the costs or the generation of energy for domestic sewage. The following provides an overview of answers to a number of general questions that the study was to answer.

1. *Can anaerobic biological treatment provide secondary or better quality for domestic sewage applications with cold temperatures and dilute organic concentrations?*

   This study confirms what has been shown in numerous small-scale studies, i.e., that the AAFEB is capable of treating domestic sewage to secondary quality. Organic concentrations in the effluent of the anaerobic process were consistently less than 20 mg/l regardless of the temperature of the wastewater (wastewater varied from 5¡C to 28¡C). The presence of dissolved gases, hydrogen sulfide and methane, and suspended solids raised the total BOD to greater than 30 mg/l in many cases. To achieve secondary discharge requirements, gaseous by-products of anaerobic fermentation must be controlled. Several options were identified in this study.

2. *Can a high-rate anaerobic treatment system eliminate the need for separate sludge handling and digestion?*

   Primary sludge can be fed directly to an AAFEB system and good conversion can be achieved. Influent suspended solids would be limited to about 250 mg/l to enable sludge retention time in the blanket in the clarifier zone of the expanded bed to be sufficiently long to achieve good stabilization. This study used a dilute wastewater. In applications where the suspended solids are more concentrated, separate sludge solubilization and hydrolysis units may be required.

3. *Is an anaerobic pretreatment process necessary for use with the hydroponic system?*

   Early development of the NFT was done with raw and primary settled sewage. It can function under these conditions; however, long-term sludge accumulations and efficient degradation and management of sludge is easily achieved in the simple anaerobic process. It makes sense to consider this as an option, but it is not necessary.

4. *What is the overall sludge production of the treatment system?*

   Stabilized sludge produced by the system would appear to be less than that produced by a primary wastewater treatment plant that included anaerobic digestion and sludge thickening. Both dry matter production and the volume of wet sludge produced by an AAFEB wastewater treatment plant were less than 45 percent of the sludge generated by a secondary wastewater treatment plant with anaerobic digestion and thickeners.

5. *Can the NFT be used to remove nutrients in a cold climate on a year-round basis?*

   Although there are many variables involved and data were quite scattered, this study showed that nutrients could be removed, at low loading rates (less than 5 cm/d application rate), to less than detectable levels on a year-round basis in plant-based systems that are allowed to reach equilibrium.

6. *What is the biomass production that can be expected in an NFT system?*

   Limited harvesting studies were conducted during this effort. The total production of roots and stalks with *Typha glauca* NFT system approached 100 metric tons (dry) per hectare per year. The biodegradability of the root mass, as interpreted from measure of the TDOM (67% of the VS) was slightly greater than that of the stalk biomass (54%). If only the stalks are harvested, about 40 percent of the total quantity of biomass could be harvested. Total biomass harvesting represents a limitation to the system because of the long time to reach equilibrium and the influence of microbial cycles on nutrient concentration.

7. *What is the effect of temperature on these biological processes?*

   Excepting for BOD reduction there was limited impact of temperature on all processes. Viscosity of the wastewater at low temperatures increased such that the effluent suspended solids levels from the anaerobic process during the coldest period of the year resulted in significantly higher carry-over of fine suspended solids. This did not influence the final suspended solids that were produced by the NFT system, however. Nutrient removal in the plant-based system is related to the secondary decomposers operating in the root mass Surprisingly, the root mass did not increase after the first year, and the average depth (about 14 cm) and the mass of the roots did not change.

8. *Are there valuable by-products other than energy that could be produced in the system?*

   The NFT is adaptable to the production of many useful by-products. The production of flowers was tested in a limited way by growing wild irises. These flourished abundantly and could represent a cut-flower market. Other products such as trees and grass turf were also found to be easily produced.

9. *What is the maximum amount of substitute natural gas that could be produced by such a system?*

   The total amount of substitute natural gas generated by the system could easily exceed a value of $50,000 per 10,000 people treated per year. The maximum would approach $250,000 per year. However, this large hydroponic system is probably not cost-effective for methane production only.

10. *Is chemical disinfection required to enable the wastewater to be used in human-contact applications?*

    Based on indicator microorganisms measured, at low loading rates the removal of pathogenic microorganisms could be high enough to be discharged without conventional chemical disinfection.

1.5.5.2 System Characteristics

The wastewater tested in this program represented a dilute sewage with highly varying characteristics with the presence of toxics in the full-scale aerobic treatment plant that at times resulted in fish kills during the study. Wastewater temperatures varied from 6 to 28¡C, had a total TCOD of 320 mg/l, BOD of 110, and suspended solids of 114 mg/l; pH varied from 9.5 to 5.8 but averaged 7.2 most of the time. Total nitrogen content was 22 mg/l. Ammonia-nitrogen averaged 14 mg/l, total phosphorus 3.9 mg/l, and sulfate-sulfur concentrations averaged 15 mg/l.

The study was conducted with continuous flow without any significant interruptions for 52 months with the bulk of the data being obtained in a 38-month phase. Important side studies included the use of outside NFT channels that were allowed to freeze during the wintertime and were taken off-line and then placed back into operation during the summer. In general, a comparison of the natural systems and these outdoor units and the greenhouse covered channels showed that greenhouse climate control increased the growing period a total of three months in northern climates where the temperature in the greenhouse was maintained only a few degrees above freezing throughout the winter months. The bulk of the plant mass in the greenhouse entered a dormant phase by mid-November and began to grow again in mid-March inside the greenhouse system.

The general experimental procedure was to test a constant wastewater feed rate until steady operating conditions were achieved, and as soon as the steady conditions were measured, a new condition was instantaneously superimposed on the treatment system. Thus, all data represent approximations of steady operations in terms of hydraulic flow rates, i.e., each average set of conditions represents only a limited period of time, usually from four to six weeks in duration. Even under this continuing stress and changing loading conditions total BOD in the total system effluent was less than 20 mg/l virtually all of the time, and most values of BOD and SS were less than 5 with many values of less than 3 mg/l were observed.

This experimental mode of operation led to the identification of more than 30 steady operating conditions for the expanded bed and more than 80 conditions for the NFT process. The average value used to represent these four-to-sixÐweek periods were typically based on three to ten separate samples from 24-hour composite samples for each parameter.

Total COD reduction is one of the more impressive removal capabilities of the system. The average influent concentration was greater than 300 mg/l, but the average NFT effluent concentration was less than 25 mg/l, indicating that the slowly available organics were efficiently consumed along with the dissolved materials such as hydrogen sulfide.

1.5.5.3 Anaerobic Sewage Treatment Feasibility With the AAFEB

The hydraulic retention times tested varied from 1.5 to 27.2 hours in the AAFEB system with most tests resulting in a hydraulic retention time of less than three hours.

The expanded bed was composed of 100-micron-diameter diatomaceous earth particles and was exceptionally stable and operated without problems throughout the entire study period. No media was added for the entire study. Constant velocities through the system were obtained by adjusting recycle rates to obtain a total upflow of 88 m^3/d in the first-stage system and 56 m^3/d in the second-stage AAFEB unit.

Early in this study it was decided to use a two-stage AAFEB system with the first stage being used as the sludge management unit and the second unit being applied as the main methane production unit. This two-stage arrangement was highly successful in managing sludge without a clarifier and achieving efficient treatment. No sludge blanket accumulated on top of the second-stage expanded bed at any time.

The small particles required in operating an expanded bed resulted in relatively low recycle rates and low energy consumption. It was estimated that head loss through the system was less than 5 cm/m of bed including pipe friction losses. Previous estimates had assumed that the recycle rate enables the expanded bed to be considered a completely mixed unit. Tracer studies confirmed that this was the case.

The most surprising conclusion was the lack of development of acetate utilizing capability in the first-stage system. At no time did the BOD removal efficiency exceed 30 percent in the first stage, and the short-term laboratory studies indicated that acetate use was minimal. This suggests that one of two things occurred in the first-stage AAFEB system. Either acetate-using methanogens were excluded from the film by rapidly growing hydrolyzing, acidifying and/or sulfate reducing bacteria, and thus were not able to achieve a significant population; or toxics that were known to be present eliminated slower-growing acetate using methanogens but enable faster-growing species to proliferate and protect the second-stage system. It is likely that sludge management within the first stage had an impact on the capability of this system.

The question of the feasibility of anaerobic treatment relates to its capability to remove organic matter at very low soluble concentrations. A comparison of previous studies showed that at appropriate loading rates the anaerobic expanded bed is capable of producing soluble organic effluent concentrations as low as several mg/l of volatile fatty acids or several mg/l of BOD. This can occur down to temperatures of 7¡C or less. Thus the concept that the anaerobic process is limited as a pretreatment process is not valid for organic removal. The by-product dissolved gases, such as hydrogen sulfide and methane, must be addressed if the process is to be used as a stand-alone process.

1.5.5.4 AAFEB Effluent SS

Suspended solids removal in the anaerobic expanded bed was the focus of a significant amount of attention. Most influent values were greater than 120 mg/l suspended solids, and effluent from the anaerobic systems was less than 40 mg/l and often less than 20 mg/l SS. Temperature had a significant effect on effluent SS. At temperatures greater than 16¡C, 70 percent suspended solids removal or greater was often observed, and 20 mg/l or less easily achieved by the AAFEB. At less than 16¡C, the suspended solids removal efficiency was often around 60 percent and resulted in equilibrium suspended solids concentrations of about 40 mg/l. Batch settling column tests indicated that these were limiting effluent concentrations.

Thus the expanded bed is capable of producing suspended solids that approach or equal the 30 mg/l secondary standard in many cases. Because the suspended solids are very fine particulate matter and are black in color, the effluent of an anaerobic treatment system is not comparable to many aerobic treatment systems with effluent suspended solids measured at the same concentrations.

Gas evolution also carries suspended solids around baffles at low loading conditions and at intermittent mixing conditions. Better baffle control of clarifier velocities above the expanded bed and outside the recycle zone could reduce effluent SS over that observed here.

1.5.5.5 Sludge Management

As indicated previously, primary sludge was allowed to accumulate and hydrolyze in a sludge blanket on top of the first-stage expanded bed. Suspended solids loading in the wastewater treatment system was complicated because of large doses of septage that were received along with other unexpectedly high inputs of solids. All of these solids additions were included in the sludge measurement values. These values were adjusted to compare to other conventional treatment systems by multiplying the values by 1.96, which is the ratio of average influent solids measured here to an average domestic sewage concentration that would have a raw sewage concentration of 225 mg/l SS. Total accumulation of solids indicated that the adjusted volume of sludge produced was 0.84 l TSS/ m^3/d, and the dry matter generation rate was 0.049 kg TS/s-d. This sludge rapidly settled to approximately 6 percent total solids in less than an hour and had the smell and appearance of a well digested sludge. It had a volatile content of approximately 50 percent of the dry matter.

An examination of accumulation of solids and their characteristics indicated that the conversion efficiency of the sludge was approximately 50 percent. A comparison of these sludge accumulation values to that generated in primary and secondary plants indicates that the AAFEB system produced 85 percent of the sludge generated by a primary plant and 45 percent of the sludge generated by a secondary system on a volumetric basis. It was assumed that the primary and secondary conventional plants used anaerobic digestion and sludge thickeners.

Wintertime operation of the system showed that the hydrolysis rates were little affected by low wastewater temperatures At retention times of around one hour and 7 °C the volatile acid accumulation was similar to that achieved at 28 °C at equal retention times. Thus the hydrolysis and acidifying bacteria were not limited by temperature in the first-stage reactor.

The test programs examined hydrolysis and acidification kinetics of solids in the AAFEB system. This largely explained the efficiency of the process. The conversion rate of sludge appeared to have a maximum of about 3 4 g TCOD/l-d, and rates at 12 °C were still equal to 1.25 g/l-d. Comparison of these conversion rates and the solids retention time achieved of 50 days or greater indicated that good stabilization could have been achieved in the sludge blanket.

Overall the two-stage expanded bed was capable of receiving minimally pretreated raw sewage, efficiently separated it into a sludge blanket, and converted it to stabilized sludge. Effluent quality from the AAFEB approached secondary at combined hydraulic retention times of less than six hours. The required retention time in the first stage may be as short as one hour, and the second stage will be longer to achieve lower loading rates and good volatile acid conversion efficiencies.

1.5.5.6 Fate of Sulfate-Sulfur in the AAFEB

Successful use of anaerobic treatment systems will rely on the capability to manage odors and sulfides in effluents. In this study, the average influent concentration of 15 mg/l sulfate-sulfur was reduced to approximately 10 to 12 mg/l sulfide-sulfur in the first-stage expanded bed. Surprisingly, no additional sulfate reduction occurred in the second stage even though readily available organic matter usually was present.

Attempts were made to eliminate dissolved sulfides using a process developed earlier that involves addition of insoluble iron salts to provide *in situ* control. Ferric phosphate and ferric oxide were added in stoichiometric quantities to the influent wastewater for short periods of time. The results showed that the dissolved sulfides could be reduced to less than detectable concentrations by the addition of these insoluble iron compounds. This treatment eliminated the odor and the oxygen demanding problems associated with the dissolved sulfides in the anaerobic effluent. The economic feasibility of this treatment remains to be demonstrated.

Fecal coliform counts were reduced by nearly one order of magnitude from 10^6 to 10^5 colonies per 100 ml of wastewater at relatively long hydraulic retention times in the AAFEB.

1.5.5.7 Hydroponic NFT Treatment of Domestic Sewage

Overview of System

Relative few cold-temperature hydroponic applications have been used in domestic sewage treatment. Most plant-based treatment studies have concluded that nutrient removals are problematic and that ammonia remains a problem in many applications. These results have supported a continuing debate as to whether plants, in fact, have any role whatsoever to play in waste treatment systems. It would appear that this statement grows out of a lack of consideration of long-term equilibrium applications of plant systems and/or the oxygen transfer capabilities of various aquatic systems that have been examined.

A total of 56 different hydraulic retention times were examined in this four-year study of the nutrient film technique (NFT). Hydraulic loading rates varied from 0.4 to 73 cm/d. The NFT channels were horizontal units, and resulting liquid levels varied throughout with the highest at the entrance and decreasing to shallow at the end of the system. No effort was made to force wastewater through or over the root mass.

The most impressive characteristic of the NFT system was the high clarity of effluent under all conditions. The suspended solids in the effluent were almost always low, less than 5 mg/l, and these solids were large biocoagulated form. Significant suspended solids only occurred intermittently when the system was disturbed, for example, during harvest when people were walking on the plant roots themselves and crushing and disturbing the plants, or immediately following relatively large instantaneous flow changes.

An examination of the impact of temperature on numerous water quality parameters indicated little seasonal impact or low-temperature effects on the system. Maintaining the greenhouse temperature only a few degrees above freezing resulted in a drastic influence on the plant itself, since dormancy would occur at the beginning of each winter. This is not to say that the plants had no effect on the water pollutant removal capacities. Rather, the decrease in nutrients in the wintertime when the plants were largely dormant was likely related to the nutrient storage mechanism in the plant root matter as well as the uptake by the secondary decomposer population in the root zone.

The high and efficient removal of nutrients in cold temperatures and dormant plant systems after long periods of time indicates that the system was in equilibrium and different nutrient cycles were capable of controlling nutrients at all times

Characterization of NFT Roots, Humus, and biomass

The average root volume in the nutrient film was approximately 70 l/m^2. This was confirmed both with tracer studies conducted to measure the hydraulic retention time and direct measurements of the root volume. If the void space around the roots was 50 percent of the total volume occupied by the roots, this would indicate a total root space of approximately 140 l/m^2 or a depth of 14 cm. The depth of the root mass in all NFT units for all plants varied between approximately 10 cm and 28 cm.

Although it had been anticipated that root mass would accumulate this was not the case. The maximum volume and mass of roots occurred in one year. Thus the annual production of roots entered into the decomposer cycle and impacted nutrient uptake

Shoot densities varied between 50 and 150 plant stalks per square meter, with typical plant density of approximately 100 per square meter. The more dense channels were planted with 40 stalks per square meter. Cattail stalk densities in natural stands vary between 5 and 20 per square meter.

Organic matter that could be washed free of the roots was referred to as humus and represented a highly stabilized sludge with an ash content varying between 60 and 70 percent of dry weight. Accumulation of this material averaged approximately 2.7 kg/m^2-yr. After more than 1,500 days of accumulation, this humus matter was approximately equal to the rhizome dry mass with approximately 27 dry metric tons per hectare. The N accumulation rate in the humus varied between 18 and 40 g/m^2-yr and the phosphorus between 36 and 57 g P/m^2-yr.

At a hydraulic loading rate of 7.5 cm/d, the total hydraulic retention time in the system was measured with tracers and found to be 21.6 hours. Over the wide range of hydraulic loadings tested, this resulted in a hydraulic retention times in the NFT varying between 2.2 and 400 hours. The more efficient nutrient removals and indicator organism destruction occurred at hydraulic loading rates of 5 cm/d, which correlates to hydraulic retention time of the system of approximately 32 hours.

NFT Organic Removal

Water temperature in the NFT channels was generally cooler than air temperatures and varied from less than 5 °C to 24 °C. Even though some conditions were loaded heavily with suspended solids and BOD, effluent concentrations were always low. For example, at one heavy loading rate of 25 cm/d the total influent BOD was equal to 360 mg/l, and suspended solids averaged 245 mg/l. The effluent total BOD was 8 mg/l, and suspended solids was 4 mg/l.

A general relationship was determined between effluent concentration of BOD and suspended solids and BOD loading rates in g/m^2-d. Values tested ranged from 1.1 to 89 g/m^2-d (9.8 to 800 lbs BOD/acre-day). In general, the effluent BOD was related to the surface area loading rate and was always less than 20 mg/l up to a loading rate of 20 g/m^2-d. Increases of up to 50 g/m^2-d did not increase effluent BOD above 25 mg/l.

There was no relationship between suspended solids loading and effluent quality since effluent suspended solids were always low.

Fate of Nitrogen and Phosphorus in NFT System

Data analysis was conducted to correlate resulting effluent total nitrogen concentrations and ammonia-nitrogen concentrations at different loading rates at temperatures above 16°C and below 16°C. No temperature effect was observed. At no time was any nitrate detected in the effluent The total ammonia-nitrogen values were proportional to the loading rates at hydraulic applications between 5 and 10 cm/d with low to undetectable levels at 5 cm/d wastewater applications or less. Little nitrogen removal was observed above hydraulic loading rates of approximately 10 cm/d. In other words, nitrogen removal mechanisms were not effective above this hydraulic rate. At hydraulic loading rates of less than 3 cm/d, all forms of nitrogen in the effluent approached zero. This results in surface area requirements of greater 30 m^2/s-d (28 acres per MGD). At TKN loadings of less than 0.8 g/m^2-d, nitrogen removal efficiencies were in excess of 90 percent on a year-round basis.

The fate of phosphorus was similar to that of nitrogen in that removal efficiencies above hydraulic loading rates of 10 cm/d were low, and below 10 cm/d the total ortho phosphorus decreased proportional to loading. At 3 cm/d, ortho phosphorus was below detectable concentration for a number of measurements

To explain rates on a seasonal basis, batch nutrient uptake tests were determined with ammonia, nitrates, and ortho phosphorus added to the plant system. The maximum ammonia nitrogen removal rate in February was 0.84 g NH_3/m^2-d. This increased to 1.3 g $/m^2$-d in the spring. Nitrate removal rates were similar to ammonia rates. Total nitrogen removal was approximately 2.5 g/m^2-d. Phosphorus removal rates were fairly constant at a maximum rate of 0.5 g P/m^2-d.

The comparison of nutrient and metal composition of cattail biomass and humus was useful to determine the fate of materials in the system. Macronutrients (N, K, and P) in the cattail biomass were all substantially increased over the wild concentrations with nitrogen and potassium three times that of wild concentrations Phosphorus concentration increased four to ten times over wild concentrations. Ca, Mg, S, Na, Fe all showed increases in the plants over the wild background levels.

The increase in plant tissues of macronutrients was relatively small compared to the large quantities and concentrations in the humus material. Cadmium was approximately 0.1 ppm in wild cattails, and the NFT cattails contained between 0.1 and 0.4 ppm, showing little uptake in most cases. The humus had 2.4 ppm, which is similar to the concentration in the sewage sludge at the sewage treatment plant. Lead was the highest element accumulated in the cattails with 1.9 ppm in the wild with NFT cattails accumulating between 2 and 18 ppm. Sludge contained 40 ppm. The highest element accumulated in the humus was iron with a concentration of 6.6 percent of the dry weight. This indicated that interactions with phosphorus and other elements could be possible.

Fecal Coliform Reduction in NFT Hydroponic System

A general correlation was obtained between the loading rate or hydraulic retention time and indicator organism or coliform reduction. At lower loadings of 5 cm/d, coliforms were decreased by 99.99 percent or to less than 10 colonies per 100 ml of wastewater. This indicated that this hydroponic system is capable of removing indicator organisms to below discharge requirements, thus eliminating the need for chemical disinfection

Pest Management

Early in the study significant system failure occurred due to pest infestations. After integrated pest management procedures were instigated during the first year of the hydroponic studies, the damage to the system was maintained at less than 10 percent. This was done with relatively little training and at a low cost Pest management will be a common requirement for aquatic treatment systems, but the costs should be low.

Economics of the Resource Recovery Wastewater Treatment Alternative

In order to provide an economic basis for evaluating the resource recovery treatment alternative, the systems were designed for two different levels of treatment: secondary and tertiary quality effluent. The secondary quality effluent was assumed to produce an effluent of 30 mg/l of BOD and suspended solids, and the tertiary quality effluent was assumed to be less than 5 mg/l BOD and suspended solids and 1 mg/l of ammonia nitrogen and orthophosphorus.

A summary of the results of this analysis is given in Table 2. Resource recovery alternatives have substantial advantages over conventional treatment systems. Although the capital costs for the tertiary quality system does not have a 2:1 advantage over the conventional secondary systems, it is much more cost effective in lifetime analysis primarily because of lower operating costs and the energy benefits that could be derived from the digestion of the plants. A total energy value of $73,000 per year per MGD treated was assumed for the tertiary treatment system

It should be noted that one of the main advantages of the NFT system is ignored in this economic analysis. That is the production of valuable terrestrial plants. It is anticipated that a wide range of products will be produced in this system once it is implemented.

Table 2: Comparison of Costs of Resource Recovery Wastewater Treatment Systems to Conventional Systems for A Design Flow of One Million Gallons Per Day. Capital in 1991 $ Millions, Operation and Maintenance in 1991 ¢ Per Thousand Gallons Treated, Energy Value in ¢ Per Thousand Gallons Treated, and Present Value is the 20-year Total Cost Capital, O&m, and Energy Revenue

	Capital	O&M	Energy	Total present value cost
I. Secondary quality effluent				
A. Conventional	3 40	68	0	6.33
B. Resource recovery	1.64	37	0	3.24
II. Tertiary quality effluent				
A. Coventional	6 13	156	0	12.80
B. Resource recovery	5 38	48	20	6.87

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1.6 Mandate for Multidisciplinary Action,

G. Chan.

United Nations University,
14 Poivre Street, Beau Bassin,
Mauritius,
Tel: +(230) 464 2659,
Fax: +(230) 212 9236,
E-mail: 100075.3511@compuserve.com

1.6.1 Introduction

This paper is based on the Consultative Meeting Re. Recycling Waste for Agriculture: The Rural-Urban Connection, Washington D.C., September 23-24, 1996.

General Comments:

1. It is a fact that an increasing effort is being made to safely and profitably recycle urban wastes, but NOT to the point of being well established in a variety of places worldwide. There are not so many success stories from both developing and developed countries, which are spectacular enough, economically or ecologically, to deal with today's rapidly growing mountains of urban waste, which end up in overflowing landfills, open sewers and cesspits; river and ocean dumping; incinerators; and air, water and soil pollution which creates serious environmental and human health problems.

   It is true that the only answer to this huge waste problem is the successful conversion of both liquid and solid municipal wastes into valuable resources on a global scale by adding specific waste recycling requirements to development projects, and to link urban and rural communities for mutual economic, human health and environmental benefits.

   In this respect, we must not forget that even if livestock waste may not be as harmful as the urban one as far as human health is concerned, it represents a huge economic resource which can otherwise make the whole waste recycling process very profitable indeed. This is the reason why in my paper, I deal with Integrated Rural-Urban Waste Recycling – see Annex A and B of Appendix 1.

2. The specific recycling projects in the World Bank list incorporate useful recycling requirements, but they are NOT adequate enough to deal with ALL the pollutants or to recycle ALL the useful resources. There is not enough integration to use ALL the wastes as resources, and the processes are NOT effective enough to eal with ALL the pollution problems in a synergistic manner in order to obtain maximum benefits at the lowest costs.

3. Now that the World Bank has brought together more than 150 experts representing Bank, agricultural and urban interests for a consultative forum focussed on "Recycling Waste for Agriculture" ,and agreed that waste recycling is the way to go, it should be consistent with itself and stop the damage to which so many developing countries have been subjected to.

4. The recycling examples provided by most participants are archaic, and show the ignorance of recent breakthroughs by both donor and receiver countries. The World Bank should make a much better effort to disseminate the latest information on the state of the art, starting with its own field staff before they cause irreparable harm, especially in the develping counties which cannot afford to waste their limited resources on demoded and ineffective technologies.

1.6.2 Waste as a Most Important Resource

Waste recycling has had nothing but lip service all over the world except in Asia where this millenia-old practice is still being used today, and in many cases very much enhanced with modern science and technology. In central, southern and south-western China, there are huge farms and big agro-industrial factories which are self-sufficient in energy and/or fertilizer by recycling their own wastes while dealing with their massive waste problems. The World Bank should make a quick survey of such achievements, and disseminate such useful information especially to the developing countries which are looking for truly sustainable development, instead of blindly copying the present disastrous technologies which are not only prohibitive in capital and operation costs, but also inappropriate and ineffective.

My own native Mauritius is about to make such monumental mistakes in its waste management projects, doing what the forum participants have denounced as wasteful in terms of money and technology!

1.6.3 Megacity Problems

It is not good enough to just stress the magnitude of megacity problems and point out that they can only worsen as the pace of urbanization continues to accelerate, and that the megacities are already spinning wildly out of social and environmental control. Will the World Bank play a leading role on this issue, which is reverse the current trends? Will the UN Centre for Human Settlements, after Habitat II, do anything along the same lines before Habitat III?

It is stated that the World Bank is well positioned to mobilize the technical, financial, leadership, and resources needed to tackle the issue of waste-reuse. It is also taken for granted, that the World Bank along with other organizations will lead the way toward sustainable development by becoming the "product champions" of global waste recycling.

We are also gratified to see that the World Bank has voiced a strong case for immediate action to expand the relatively small scale waste recycling projects to global scale. It is also stressed that the necessary scale-up will only come when governments recognize the need for policies which are counter-intuitive and multi-sectoral -- policies which replace current linear thinking with systemic, circular or cyclical solutions.

It may be appropriate for the World Bank to issue the right directives for its own staff to convince the various governments, especially in the third world, to adopt such waste recycling policies, because they are now doing exactly the opposite to promote the wrong kinds of technologies that the consultants of some rich countries are pushing very hard with funds provided by their respective governments.

1.6.4 Future Action

What is encouraging is that we have begun a dialogue, and formed important new partnerships to break down the barriers to global-scale recycling of waste for agriculture, and create win-win-win solutions to meet economic, human health and environmental needs right down to the village level.

This is what the Integrated Biomass System of UNU-ZERI is all about -- see Annex C of Appendix 1.

I would like to suggest that a Task Force of the World Bank, made up of its top people, make a preliminary survey of success stories on waste recycling, and pay a visit to a few selected ones with the designers concerned, with a view to replicate them for demonstration to the local decision makers of the third world. Meanwhile, there should be a moratorium on existing projects to limit the damage!

It is the only way to show skeptics that there are valid alternatives to what the developing countries have been doing, almost blindly, to copy the failures of urbanization and all its waste treatment systems, and stop the rot ...

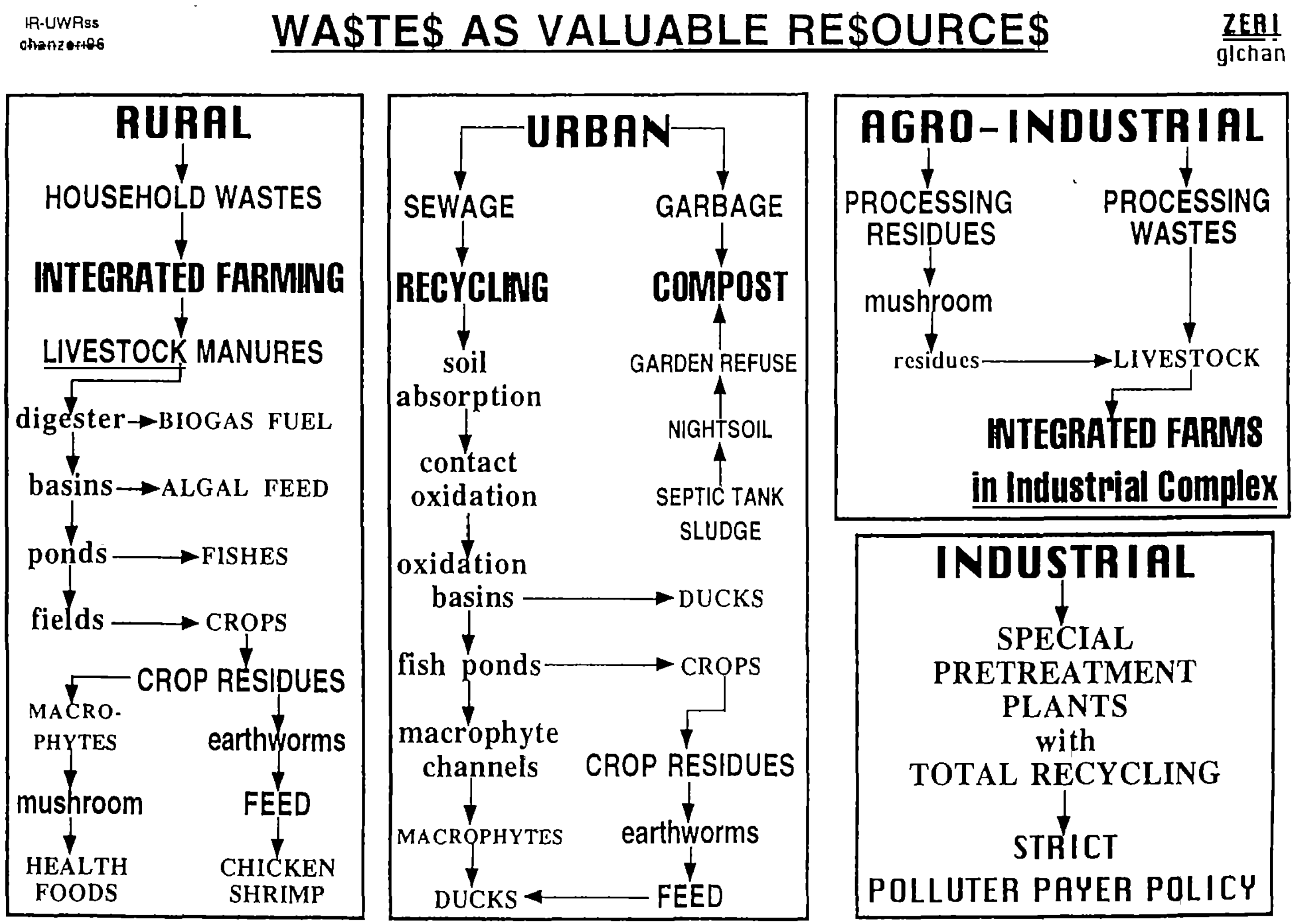
Attachments

Appendix I: Comments by Prof. George Chan on "Recycling Waste for Agriculture: The Rural-Urban Connection"

Annex A: Integrated Rural-Urban Waste Recycling for Zero Emission

Annex B: Synergistic Waste Recycling System: Objectives and Processes of Integrated Waste Recycling

Annex C: Integrated Biomass Systems: Goals of Integrated Farming Activities



Box 1: Wastes as valuable resources.

Appendix I : The Challenge in Wasting Waste, Recycling waste for agriculture: the rural-urban connection.

COMMENTS by Prof. George Chan, Environmental Engineering Consultant, Zero Emissions Research Initiative (ZERI) Program, United Nations University, Tokyo, Japan.

TO Mr. Maurice Strong, Senior Adviser to the President The World Bank, Washington, DC, USA.

Background

Mr. Maurice, Strong has known the author of this paper since 1972 when he was Executive Secretary of the First Environtilent and Developtment Meeting in Stockholm, and subsequently became the Executive Director of UN Environtment Program. He had sent his Special Adviser, Mr Marc Nerfin, to see the Integrated Farming Systems pilot projects implemented by the author in Papua New Guinea.

Mr Nerfin stated that Mr Strong had defined eco-development in Stockholm, but they both wanted to know about the first such examples which already existed in the field. Subsequently, Mr. Strong said to the author during the Second Environment and Development Meeting in Rio, where he was again Executive Secretary: "I coined the word eco-development but you have been doing it in the field years before that. I have sent your papers to various agencies and hope at least one of them will respond positively one day. Give them time to react to our new visions ...".

These words of encouragenemt from the World Authority on Environment and Development have inspired the author condiderably, despite his advanced age, and hardened his determination to push his work to global heights. His chance came 2 years ago, after more than 30 years of constant struggle, when the United Nations University implemented the Zero Emisions Research Initiative (ZERI) program, and appointed him as Consultant to direct the first pilot projects in Fiji, Namibia and Tanzania. Today, his expertise is sought worldwide, even from the developed world!

Introduction

I wrote this paper after the meeting on RECYCLING WASTE FOR AGRICULTURE held at the World Bank on 23-24 September 1996 in Washington, DC, USA, where I resented a slide show on INTEGRATED RURAL-URBAN WASTE RECYCLING FOR ZERO EMISSION to a packed audience -- see Extended Abstract in Annex A.

The Rector of UNU, his Deputy, my Supervisor who founded ZERI, and the Director of ZERI-USA told me afterwards that the comments they gathered from the audience were that my talk was the best of the whole meeting. Hence the reason for this analytical paper -- to justify those favorable comments from the audience.

My presentation was the ONLY one in that most important meeting which dealt with ALL the wastes generated by the rural, urban and agri-industrial sectors, and their total recycling as renewable resources for complete environmental protection.

Format

The format used is in conformity with the FOUR titles provided by the World Bank and World Engineering Partnership for Sustainable Development (WEPSD) for the Consultative Meeting on Environmentally Sustainable Development (ESP 96), which was attended by representatives from:

- World Bank and other lending insitutions
- Private business interests
- Government departments
- Universities & Research institutes
- Non-government organisations

My views are from a luckier representative of the Third World which has NOT benefited much, if at all, from the spectacular progress made after World War II, when the United Nations and its numerous agencies, and nearly all the organisations and businesses present at ESP 96, were created -- supposedly to help the poorest of the poor in most developing countries. But from the remarks made by most of the participants in and out of the meeting hall, with unanimity from those of the Third World, such help has been lacking for various reasons which must now be seriously addressed and which include:

inappropriate, uneconomic, anti-social and/or environmentally degrading technologies, but most important of all, unpreparedness from the part of the officials concerned for the main issues discussed in the theme chosen by !he new President of the World Bank himself:

"RECYCLING WASTE FOR AGRICULTURE".

The first TWO words must be new to the development strategies of almost all the world bodies and sponsors present, which were not particularly organized for such tasks. So this must be a real challenge for the World Bank, WEPSD, United Nations Development Programme, Food & Agriculture Organization of the United Nations, World Health Organization, World Management International, Camp Dresser & Mckee Inc., Montgomery Watson, CH2M HILL, N-Viro International Corporation, CIESEN, Rodale Institute, and Fluor Daniel. I feel privileged indeed for the unique opportunity to contribute to such important issues among such an impressive group, after more than 30 years of personal involvement in recycling of ALL wastes for development at global level. Now we are talking the same language -- at least we all hope so!

A. Country cases

- Use of waste water & stabilization pond effluent for agriculture and aquaculture
- Recycling treated wastewater for farming, industry & groundwater recharge
- Composting of municipal solid wastes and reclamation of municipal sewage
- Use of municipal solid waste and sludge on farms, and farmers' acceptance
- Agro-energetic recycling of compost, industrial and farm wastes in urban areas
- Waste and wastewater management for sustainability and polution control

1. What should the World Bank and other important actors do to advance recycling of waste for agriculture?

The country cases, which took the first full day in plenary sessions, showed nothing innovative to me, as I said just before the last session was closed. One participant challenged me as we met near our hotel, and wanted to know if I had anything innovative to offer to the meeting.

"I wouldn't have stuck my neck out if I didn't have a few things up my sleeve", I replied. "Please be there when I talk to-morrow afternoon.".

However, it was gratifying to see that some countries, poor as well as rich, have started to use waste and wastewater as valuable and renewable resources for various agricultural purposes. There should be more co-ordination and exchange of ideas, particularly among developing countries, some of which have centuries of proven experiences, in order to save both time and money to implement urgent action, and stop the rot that has settled in most countries, especially the poor ones.

All the case studies described in Latin America, Middle East, Africa and India were so ineffective, unhygienic and/or even archaic relative to new biotechnological breakthroughs already proven although not time-tested yet and, especially so, to the innovative standards of ecological engineering advocated by some academics & field researchers during this decade. The systems mentioned have proved to be dangerous, badly designed with various functional problems, and even complete failures.

These have already been replaced with alternative or innovative techniques which are more ingenious, mostly based on ancient practices which have been newly enhanced with modern science and technology, and work so much more effectively and efficiently. It was very unfortunate to find out that most of the participants knew practically nothing, about such new and crucial development.

A few have even reinvested the wheel, ignoring what has been done and is highly developed elsewhere, and claimed as if they were new inventions from some rich nation. One case on digestion of agro-industrial wastes was really pathetic!

The examples from USA were so complex and costly that no third world nation should ever touch them, as they were more inappropriate than all those which have already been transferred to some developing countries and have proved to be eventual failures because they used imported equipment, fossil fuel energy and chemical processes, when tropical places should use locally-built and simple structures , direct or indirect solar energy, and biological or biotechnological processes to capitalize on their warm climatic conditions and their hard-working microbes for maximum yield at the lowest possible costs.

The so-called sustainable technology demonstration project from China was a real disaster, as the author muddled through incomprehensible theories, when his country has so many proven and time-tested examples of sustainable development to show the world, but has preferred to import costly and environmentally degrading technologies from the rich countries, without the technical and financial capabilities to solve or even control the related adverse pollution.

It is obvious that what the World Bank and other important actors should do, without any delay, is to put some order in the various projects made by individual countries. And make sure that no time and money are waste in reinventing the wheel. This should be followed by concerted efforts to promote recycling of wastewater in more countries, rich as well as poor, emphasizinig that they are renewable and valuable resources which no country can afford to waste.

2. How should national, regional, and local stakeholders (including governments and non-government organizations) be engaged to advance recycling of waste for agriculture?

What the World Bank and other important actors should do is to call an expert advisory committee consisting of knowledgeable members of the few organisations seriously dealing with recycling of urban, rural and agri-industrial wastes for agriculture and economic development, and ask them to prepare a plan of action for the bank officials to implement instead of letting them continue to flood the third world with ineffective and inefficient systems designed under totally different conditions, as an academic from UK rightly said.

I have a list of 10 such institutions I can submit to the World Bank, and they are only those for which I act as consultant or adviser. There must be some others which should not be difficult to locate around the world. Meanwhile, the World Bank can make a thorough survey of such institutions, their status in their own countries and involvement overseas, and prepare a comprehensive fist of future collaborators.

The time has come for all of us to work together to solve common probems which are threatening our only globe. The solution is in the recycling of our waste on site of in our own neighborhood, instead of shifting the muck elsewhere to create new problems.

3. What follow-on actions should be taken (during the next 12 months) to advance recycling of waste for agriculture?

There should be at least one country chosen from the regions of Asia, Africa, Latin America and Occania for urgent demonstration projects of proven technologies, with appropriate modifications to suit the local conditions. The main criteria for the choice should be the cultural acceptance of waste utilization, and the most favorable conditions for success because of government and population involvement.

I suggest the following countries, where my partners are already involved in successful demonstration projects of integrated livestock-fish-plant systems, and small & decentralized sewage treatment plants so that we do not have to start from scratch:

i. **Vietnam**, in the province of Songbe in the southern part of the country, where the subsoil is suitable for brickmaking. The objective is to prove that under such conditions, which are quite common in many countries, the construction of the project is paid by the soil sold for brickmaking, with a substantial surplus to operate all the farming and agro-industrial activities. The local district government has already put 200 hectares of such land at my disposal for development of individual family integrated farm units of 1.2 hectares each, and the required funding is for provision of the various required expertise under my supervision.

ii. **Mauritius**, in the vicinity of the Government Agriculture Research and Experimental Unit at Curepipe, where it is intended to demonstrate the Complete Recycling of all Rural, Urban and Agri-Industrial wastes. The wastes come from an existing farm with 100 milch cows, a housing estate of over 200 units, and an adjacent municipal garbage transfer station. The project consists of a sustainable Integrated Farming System; an Integrated Sewage Plant with biomass nutrient recycling; and an Integrated Composting Station to produce rich and safe compost within 21 days.

iii. **Brazil**, in the small towns of Petropolis outside Rio de Janeiro, where Hamburg Environment Institute has built, with the help of local institutions, a small but successful sewage treatment plant at Sertao to demonstrate that small communities can afford such a facility, now enjoyed by big cities only. The Mayor of Petropolis has committed a sum of US$200,000 as matching fund on a dollar to dollar basis to help other small communities to have similar facilities.

iv. **Fiji**, outside the town of Larni, at the Montfort Boys Town where the Brothers of St Gabriel are training 140 boys from the poorest of the poor families of Fiji and some other Pacific islands in various trades. It already has 19 small and shallow fish ponds, with chickens and sheep providing some of the manure required to fertilize the ponds for fish culture, and the rest of the manure is purchased. The school is already self sufficient in fish, chicken and less than half of the mutton. The United Nations University is building an integrated livestock-fish-plant demonstration project to enhance the fish production in big and deep ponds; to supply all fertilizers for the plants on the dykes and half the surface of the ponds; and eventually to produce all the feed required by various livestock. It will also demonstrate the use of spent grains from a nearby brewery, with prior utilisation as substrate for culture of mushrooms and earthworms as food and feed to break down the lignocellulose before feeding the more digestible and even more palatable residue to livestock.

B. Issues I

- Institutions, economics, and political economy.
- Health, safety, and quality control.
- Marketing and transportation.

1. What should the World Bank and other important actors do to advance recycling of waste for agriculture?

Looking at the situation of agriculture worldwide, the picture cannot be grimmer, al caused by indiscriminate use and abuse of agrochemicals from the huge commercial farms down to the humble family plots in famine-prone countries, while piles of livestock wastes are left to rot and pollute the whole environment on cattle ranches, or the family is so poor that there is no livestock to produce the wastes. At both these extremes, agriculture suffers. There is no hope that monocultural crops will ever turn to organic farming, but some effort has been made in some smaller farms to use livestock manure in so-called organic farms. Unfortunately, the extra labour to do such dirty work is not only hard to find but it is also very costly, making such production uneconomic, with higher market prices which are not always accepted by the public. As for the family farm, it should never have joined the agrochemical system, and its only hope is to own some small livestock to provide the manure for its crops with emphasis on foods and basic goods for local consumption.

So the present agricultural system can never solve these problems of pollution; costly and similarly polluting agrochemicals; labour-intensity; and socio-economic viability. It also creates unnecessary transportation and marketing difficulties.

What the World Bank and others should do is to promote as which uses the wastes of livestock as inputs for aquaculture; the wastes of aquaculture for agri-forestry, and the agri-forestry wastes for livestock, as shown in annex B.

2. How should national, regional, and local stakeholders (including governments and non-government organizations) be engaged to advance recycling of waste for agriculture?

Presently, most countries just let their huge volumes of wastewaters, with or without treatment, flow into rivers or lakes and eventually to the sea. Then new water is used for irrigation, wasting so much of a limited or even scarce resource. Considering that sewage only contains 1% of pollutants, and the relatively high capital and operational costs of treatment, it is sheer lunacy to let such water go to waste.

It is true that addition of industrial chemical and even toxic wastes render the treated sewage effluent non-usable for agriculture, but it is the role of responsible local government to prevent such practices, and enforce the pretreatment of such undesirable wastes by the polluters themselves before allowing them to discharge the acceptable effluent into the municipal sewerage system.

So it is the responsibility of everybody concerned to promote the recycling of wastewater in integrated agri-industrial activities, provided that the treatment is of acceptable standard besides being economic, as outlined in Fig. I of Annex A.

3. What follow-on actions should be taken (during the next 12 months) to advance recycling of waste for agriculture?

The linear systems presently dominant in practically the whole world have not been conducive to recycling of wastes for agriculture, because of the tedious and costly way of applying the wastes in the field. They also suffer from pollution from those wastes and the excess agrochemicals used because it is too costly to treat the wastes or to apply the chemicals in smaller and more frequent doses. Such practices become more acute in the developing countries which have to import almost all the inputs, when their traditional systems were all based on local and free resources.

So the economic and ecologic factors become very important in the system used for agricultural activities. The follow-on action should concentrate on analysing the existing recycling systems around the world, and coming up with an appropriate demonstration and training program for the four chosen countries mentioned above.

C. Issues II

- Wastewater in agriculture
- Biosolids in agriculture
- Special waste streams in cities

1. What should the World Bank and other important actors do to advance recycling of waste for agriculture?

The World Bank and other important actors should facilitate the use of solid wastes and wastewater in agriculture in both rural and urban sectors. The present burial of municipal garbage, nightsoil, septic tank sludge and garden refuse in landfills has created huge problems of gas and leachate emissions which have come back to haunt the communities which created them, but a few generations later and as greenhouse gases or highly toxic substances.

Composting of these solid wastes have also proved to be useless, because the system takes so long while half the nitrogen content escapes into the atmosphere as ammonia gas, leaving a very poor compost which farmers dislike. Not only is it bulky to transport and apply to the field, but it also requires topping up with urea. So eventually the farmers end up using chemical fertilizers exclusively.

The present system of wastewater treatment which concentrates on converting the organic matter into inorganics, and discharging the highly mineralized effluent into bodies of water has created problems of eutrophication and excess heavy metal concentration in aquatic and terrestrial foods, with potential environmental and health hazards. The system is designed for temperate climatic conditions, using expensive structures, fossil fuels and chemical processes, which are so costly to build as well as operate that even the richest countries cannot afford to have full primary, secondary and tertiary treatment, and have to seek temporary waivers which become permanent. Things become worse when such an inappropriate system is also transferred to the tropical countries where they are so ineffective and inefficient that, sooner or later, they break down and remain so for a long time because of lack of trained personnel or availability of spare parts.

What the World Bank and other important actors should do-Is to tell their field staff to stop promoting the archaic and useless systems of waste and wastewater treatment, particularly in the third world. On the other hand, the World Bank should ensure that their officials are conversant with new technologies, and encourage them to promote pilot projects to test their economic, ecologic, social, cultural and environmental viability -- more details are summarized in Annex C.

2. How should national, regional, and local stakeholders (including governments and non-government organizations) be engaged to advance recycling of waste for agriculture?

Many developing countries have been taken for a ride by foreign experts who forced inappropriate proposals on the gullible leaders, and end up contracting huge debts which could not be repaid because the projects did not work as claimed and required costly remedies. It has been most disastrous in the waste treatment area. The new environmental consciousness should not become another opportunity for the waste industry to capitalize on the waste issues with their outmoded systems.

The local stakeholders should thoroughly question their foreign advisers to see if they are adequately knowledgeable regarding innovative waste and wastewater treatment systems now being developed in the world, and the reasons why they are not recommending them. More important still, the advisers should be asked to state in black and white what are the problems (a whole lot of horrors exist worldwide) which will be encountered by using the systems proposed by them, and what will be the technical and financial implications. More important still, who will pay for them?

3. What follow-on actions should be taken (during the next 12 months) to advance recycling of waste for agriculture?

I have been to over 70 countries and territories during the past 30 years, advocating the integrated farming systems for the third world. I did not like what I saw in most of them, as all wastes were just left on site, hoping they would disappear, but they created many avoidable problems which could have been solved with my technologies.

Unfortunately, there is not much money to be made by the big local or foreign firms using natural technologies and simple structures without any imported complex equipment. So such systems are not extensively advertised, but are even criticized as primitive and non-performing, even by bureaucrats and politicians, often for personal interests. Sadly, only in few cases are the culprits caught, but such malpractices are more widespread than what is brought to justice in many countries, rich and poor.

The follow-on actions include an urgent change of policy from the World Bank and other lending agencies to adopt appropriate systems of waste recycling based on local climatic conditions, using solar and wind energy, biotechnological processes with optimum microbial action, and bio-diversified farming practices to grow foods and raw materials for local utilization, with the surplus processed for the best value-added products for export -- NO developing country can afford to do otherwise!

D. Towards better practise

- The way forward: implementation and bank support
- Project development and local support

1. What should the World Bank and other important actors do to advance recycling of waste for agriculture?

The World Bank should analyse thoroughly one very important statement made by a op official during the meeting that its various departments are NOT geared to the new concept of Recycling Wastes for Agriculture. This reminded me of some of the officials and operators I met in some countries, rich as well as poor, who were honest enough to admit that their waste treatment plants were not working as claimed. Such honesty should filter down to its staff in the field where many horror stories can be heard about blatant cases of intimidation by some officials to force archaic systems on the government bureaucrats and politicians of some developing countries, including my own, in favour of a few firms or some countries offering bilateral aid.

So the new President of the World Bank has touched a sensitive nerve in the "bank official-client country" relationship of his complex banking system. Unless drastic changes are introduced immediately, the "blind leading the blind" trauma will continue at the expense of the recipient nations. The future can only be worse ...

More openness is required from everybody concerned, who must admit that what they are doing is just shifting wastes from one place to another to become other people's problems, instead of recycling them for agriculture & other economic gains. The only solution is to consider wastes as valuable resources which must be properly and efficiently treated and reused not only for agriculture but also for agro-industrial development, similar to what the United Nations University is currently doing.

2. How should national, regional, and local stakeholders (including governments and non-government organizations) be engaged to advance recycling of waste for agriculture?

Many millions of dollars are at stake in the desire for developing countries to copy the rich nations in the related environment and development craze known as Agenda 21, which actually took to task the multi-billion waste industry for failing to protect the environment from development (see below), instead of an opportunity to get richer.

The stakeholders should fully investigate all cases of waste and wastewater treatment currently being considered in their countries. particularly when restrictive practices are introduced to favour certain nations and shut the door to other legitimate competitors, and denounce any sign of malpractice or blatant bribery and corruption.

3. What follow-on actions should be taken (during the next 12 months) to advance recycling of waste for agriculture?

To summarize, I would like to mention some of the technical problems we have inherited from the waste industry, which have NOT delivered the goods as we thought or as they made us believe they did, so that we can analyse them seriously and then take follow-on actions to prevent them from continuing the mess at our expense:

- The methane gas emission from landfills to the atmosphere as greenhouse gas which is worse than carbon dioxide; and their hidden leachate emission to aquifers and coastal waters which are potential health hazards to humans and aquatic life.

- The municipal sewage sludge and effluent discharge containing phosphates, nitrates, heavy metals and other industrial toxins dumped in rivers, lakes and sea can contaminate our complex food chains or cause eutrophication in our bodies of water.

- Viruses and bacteria are known to go through primary and secondary phases of treatment unscathed, and the former have survived not only complete conventional treatment but also long periods in the receiving waters and even the sea.

- Industrial chemicals and non-biodegradable detergents are not removed at all, even after full conventional treatment for municipal sewage.
- Stabilization ponds rely on algae for production of oxygen by photosynthesis to oxidize the organic content in the sewage, and only work for a limited period, because dead

algae eventually consume more oxygen than what is produced by the live ones when the ponds start to deteriorate until they stop functioning and end up as a huge mess. Meanwhile, a scum formation invades the surface & spreads continuously, interfering with photosynthesis to make matters worse as the silt builds up. Cleaning of such ponds is a messy operation which is often delayed until siltation is complete.

- High-aeration ponds only delay the de-oxidation problem, and is so costly in energy input that no developing, or even. developed, country can afford it.
- Conventional composting loses half the nitrogen content, which is not very high in municipal garbage to start with, resulting in very poor compost which cannot be easily sold to farmers (new methods, which have solved such problems, are ignored).
- No effective and efficient treatment system exists for livestock wastes, which are so costly that no farmers are prepared to use it, resulting in considerable quantities of nutrients being lost while polluting the whole environment.
- Plus many other residues or wastes, some very toxic, which are just ignored ...

Conclusions

There is no doubt that the World Bank, WEPSD, the UN agencies, and the private firms face a huge load of problems created by wastes and wastewater worldwide, and that the existing treatment technologies leave a lot to be desired. The only solution, from the economic, ecologic and social aspects, is to deal with wastes and wastewater as renewable and useful resources which should be recycled intelligently in integrated biomass systems advocated by the United Nations University. Instead of starting from scratch, and waste time & money, it makes sense to collaborate with UNU -- Annex C.

Box 2: World Bank: Recycling wastes for agriculture, summary.

WORLD BANK : RECYCLING WASTES FOR AGRICULTURE

IR-UWRs
chanzeri96

SUMMARY

INTEGRATED WA$TE RECYCLING

Decentralized Small Gravity-Flow Integrated Sewage Plant in RURAL Vicinity
USING
Physical Separation and Various Simple Biological and Biochemical Processes for MAXIMUM Effectiveness

OBJECTIVE :
Biomass Nutrient Recycling

Decentralized Family Integrated Farming System to Use RURAL/URBAN Wastes Economically & Ecologically
USING
Output of Any Process as Free Means of Production for Subsequent Processes with MAXIMUM Efficiency

OBJECTIVE :
Total Resources Recycling

Decentralized Rapid and High-Quality Garbage/Sludge Composting in SUBURBAN Areas
USING
Forced Aeration Windrows & Very Rapid Nitrification for Microbiological Processing with MAXIMUM Economy

OBJECTIVE :
Forced Aeration Composting

Annex A: Integrated rural-urban waste recycling for zero emission, extended abstract.

World Bank Partnership for Sustainable Development

Recycling Waste for Agriculture : The Rural-Urban Connection

RURAL areas have adequate land to recycle on site ALL the wastes generated by humans and their farming occupations (human excrements, household wastes, farm manures, crop residues & macrophytes), converting them into biogas energy and fertilizers required by the rural communities to grow all the food, fodder, fibre and various essential raw materials to meet all their needs with a substantial surplus for local trading and for export to pay for much-needed equipment import.

Where water is adequately available, the recycling is made easier by having it done in large and deep ponds which not only store water for agricultural purposes, but can be used for polyculture of fish and macrophytes as well, thus increasing rural biomass productivity many-fold per unit surface area (1).

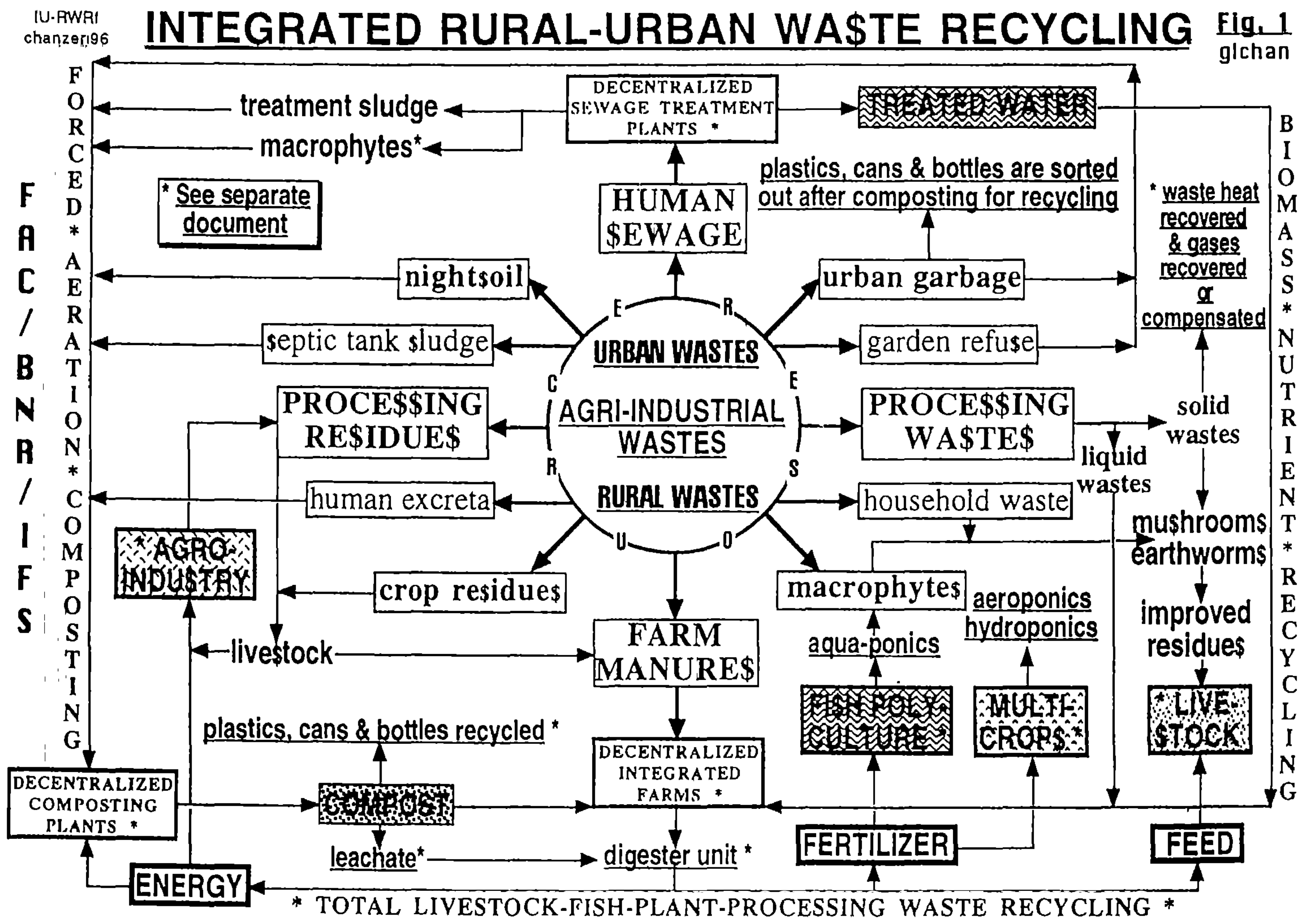
If the climate is on the warm side, as in the tropics, such rural life system can be operated on a totally sustainable and highly rewarding basis year-round. In fact, all the human, livestock, aquacultural, agricultural activities and even agro-industrial processes have been put in an ever-expanding cycle in certain countries during the course of many centuries, and are still operating today. Recently, they have been enhanced with modern science & technology into what is now termed "Integrated Biomass System for Total Resources Recycling" (2).

However, URBAN areas have created new and more complex waste problems (human sewage, nightsoil, septic tank sludge, urban garbage and garden refuse) which require more water, transport fleet, landfill space and labour. Because of inadequate funding for ever-demanding urban services, most of those responsible for increasing pollution and environmental degradation. Wastes are responsible. They are most acute in the developing world which is blindly copying the sad pattern of urbanisation adopted in the developed nations, that cannot themselves cope with the critical situation which is getting worse all the time.

To make matters much worse, INDUSTRIAL complexes emit chemical and even toxic wastes which require costly solutions that not even the richest nations can afford, and have created so many disastrous problems worldwide. Many countries have made terrible mistakes by transferring such polluting industries to their front yards from the rich ones, where such industries are prohibited (3). But there are also economic and ecologic solutions to most AGRO-INDUSTRIAL wastes, which can be dealt with by innovative and cost-effective systems that are complementary to the Integrated Biomass System mentioned above (4).

This paper describes the Rural-Urban Waste Recycling Integration, which deals with ALL the rural, urban and agro-industrial wastes, as shown in Fig. 1. The urban problems are dealt with by decentralized and efficient processes in the "Low-Cost Liquid Waste Treatment Plant with Biomass Nutrient Recycling" (5) and the "Rapid Solid Waste Treatment with Forced Aeration Composting" (6) which have been tried successfully during the past decade or two, and their residues can be incorporated with equal success into the Integrated Biomass System -- ALL for the ZERO EMISSION strategy of UNU (7).

Box 3: Integrated rural-urban waste recycling.



Annex B: Zero Emissions Research Initiative (ZERI), synergetic waste recycling system.

Utilization of the Wastes of One Process as Input for the Following Ones, as Shown by Overhead Projection at the World Bank Meeting, September. 96.

Objectives and Processes of Integrated Waste Recycling:

Effective & efficient uses of wastes

- Almost all wastes are undesirable BUT some are unavoidable: without them as needed resources there can be NO meaningful development which is sustainable and without aid or subsidies.
- All URBAN wastes are recycled in decentralized facilities.
- All RURAL wastes are recovered and reutilized on site.
- All AGRI-INDUSTRIAL wastes are inputs for integrated farms.
- But non-biodegradable chemical wastes are NOT included.

Types of wastes for integrated recycling

- URBAN: Human sewage - Nightsoil - Septic tank sludge - Urban garbage - Garden refuse
- RURAL: Farm manures - Crop residues - Macrophytes - Human excrements - Household wastes
- AGRI-INDUSTRIAL : Biodegradable processing residues - Processing wastes

UNU Zero-emission strategy

- Total utilization of natural resources within a closed production system
- Most effective under wet tropical conditions in low-lying and even marshy lands using ingeniously-designed integrated biomass systems
- Biotechnological processes using simple systems and local resources
- Enhanced by natural and simple but appropriate technical means
- Recycling of residues from any process as input for subsequent ones

Integrated biomass systems

- In the context of URBAN-RURAL connection: 3 Independently developed systems are synergistically combined to meet the most stringent requirements of Zero Emission Research Initiative;
  1. Biomass nutrient recycling of decentralized sewage plants
  2. Most efficient processes of forced aeration composting
  3. Integrated livestock-fish-plant-agri-industry system

Human sewage

- Contains huge volume of water with only 1 % organic pollutants
- Gravity flow in small sewerage system for every catchment area to various decentralized waste treatment plants in rural vicinity using physical separation and many simple biological processes
- Residues are further treated in decentralized composting plants
- Treated water is recycled in decentralized integrated farms

Nightsoil-Septic tank sludge-Urban garbage- Garden refuse

- To decentralized composting plant for making high-quality compost
- Human wastes are decomposed anaerobically by bacterial action
- Gases are constantly oxidized into inorganic nutrients as fertilizers
- Heat from decomposing garbage is adequate to kill ALL pathogens
- Garden refuse are rapidly mulched under favourable conditions
- Plastics-cans-bottles screened out after composting for recycling
- Leachate is further treated in decentralized integrated farms

Farm manures - Human excrements

- Wastes are washed 2-3 times daily into a properly-designed digester for up to 60% BOD reduction and production of biogas energy
- The digested effluent flows into a series of long and shallow basins for a further 30% BOD reduction and production of algal feeds
- The effluent then flows into big and deep ponds for final treatment and fertilizes growth of plankton as feeds for polyculture of aquatics

Crop residues - Macrophytes - Household wastes - Processing residues

- Substrate for mushroom culture while lignocellulose is broken down
- Residues become more digestible & even more palatible for livestock which need feeds not only for growth but to produce valuable wastes
- Bio-process converts non-edible biomass into high-value products
- Also substrate for culture of earthworms as high-protein feeds
- Residues after earthworm culture are used for soil conditioning

Processing wastes

- Spent solids, wastewater, gas emissions & heat losses always pollute
- Only small- fraction of solids used leaving much spent solid wastes
- Excess water used for washing creating big volumes of liquid waste
- Such huge volumes of solid & liquid wastes are efficiently recycled
- Gases emitted during fermentation are recovered & reutilized on site
- While others are compensated for with carbon sinks & conservation
- Excess heat from engines or processes recovered with heat exchangers

Decentralized integrated farms

- Small farms, including family ones, are mostly of low productivity
- Lacking in means of production: feed, fertilizer, energy, water, money
- Results are low output & poverty or high produce cost & bankruptcy
- Livestock produces wastes which are transformed into energy for industry to produce goods and fertilizer for ponds to culture fish
- Fish produces wastes which are converted into fertilizers to grow plants as food for humans & feed for livestock on integrated farms

Decentralized sewage plants

- Municipalities cannot afford conventional sewage treatment plants because of centralization, high capital investments & operation costs
- Use decentralization, small gravity sewers & integrated sewage plants
- Emphasis on nutrient recycling with simple physical & biological means
- Use self-sustaining livestock, fish and plants to recycle all nutrients
- Alternative is to direct the sewage to decentralized integrated farms

Decentralized composting

- Conventional composting has odour, vermin, gas & leachate problems
- Poor quality compost because half nitrogen content lost as ammonia
- Use forced aeration system which is covered in isolated windrows, with high temperature of decomposing garbage killing all pathogens, and intermittent air supply oxidizing all gases into stable nutrients
- No escape of leachate which is collected and treated separately

Importance of livestock wastes

- Livestock wastes are the biggest sources of pollutants in the world
- They foul the air, mess up the soil, and deoxygenate bodies of water
- Yet they are valuable resources which should be properly utilized
- Livestock plays a very important role in integrated waste recycling
- It requires balanced feeds to grow well and provide daily wastes which are essential raw materials to produce energy & fertilizer for integrated farming systems which are self-reliant & self-sustainable

Importance of fish culture

- Water is another valuable resource which is NOT adequately used
- It is wasted all over the world by just flowing in rivers directly to sea & by dumping huge volumes of wastewater into costly sewage outfalls
- River water should be diverted into big & deep ponds for polyculture of fish and macrophytes as food and feed in a self purifying system
- Treated sewage effluent encourages growth of plankton as fish feed

Importance of plant storage

- Excess nutrients in fish ponds & bodies of water cause eutrophication
- Deforestation destroys trees & vegetation which use carbon dioxide
- These two problems are solved by growing more crops on integrated farms to supply nutrients in foods and provide carbon sinks in trees
- Without plant storage, excess nutrients make algae proliferate and kill fish in ponds, and excess carbon dioxide create green house warming

Importance of agri-industry

- With abundant means of production on integrated farms, there is NO problem of having increased production of livestock, fish and plants
- New problems of excess produce preservation or marketing may arise unless agri-industry is established to process surplus foods into goods
- Besides physical preservation such as drying, smoking, pickling, salting, sugaring and canning, microbial processing is done for added value

Synergistic & other benefits

- All residues in the integrated system are recycled as resources input
- Constant provision of own means of production ensures timely supply
- Work can be spread out to suit particular schedule of any family
- Various farming activities can be modified to meet special needs
- Production independent of external influences such as price or freight
- Maximum profits at lowest production costs & no inflationary effect

Requirements for successful operation

- Adequate clay is available where integrated farm is constructed
- Adequate supply of water available for the fish ponds at all time
- Adequate but small hydro power and wind energy for agri-industry
- Adequate solar energy for integrated farming and sewage systems with sufficient land for livestock, fish, plants and agri-industries
- appropriate training for integrated farmers, and strong political will

Compliance with ZERI philosophy

- ALL Urban, rural and agri-Industrial wastes are treated & reused
- Mandatory for other industries to have waste pretreatment on site
- Can be self-sufficient in livestock, fish, plant & processing operations
- Can be stand-alone and self-reliant enterprises in any rural areas
- Can always make best quality products at very competitive prices
- Very few environmental, ecological, supply or production problems

Annex C: Integrated biomass systems, United Nations University ZERI-BAG Programme

Introduction

The United Nations University is already implementing, in its Zero Emissions Research Initiative (ZERI) programme, some pilot projects to demonstrate that it is possible to satisfy human basic needs of water, energy, foods, fibres, shelter, employment and more in an environmentally sustainable manner and with socio-economically viable benefits for everybody. They use appropriate science and technology, and involve government, Academics, farming and industry in a synergistic effort, which works best in the wet tropical regions of the third world.

The pilot projects are based on Integrated Biomass Systems which allow individual integrated farms to stand alone and be completely self-reliant as far as total biomass recycling is concerned. Moreover, they only use locally available resources, but they require the investment capital to provide the one-shot structures that any agro-industry can provide within its planning requirements to eliminate its waste problems right from the start. It will only work with biodegradable wastes,

which will be distributed as free inputs to the surrounding integrated farms and recycled completely in the various livestock, fish, plant and processing activities to achieve the zero emission objectives. It excludes non-biodegradable chemical and toxic industrial wastes, which cannot be recycled in this biotechnological manner.

Such a ZERI approach dissociates itself from the conventional concept of aid which perpetuates undesirable dependency and ties down poor nations to a global socioeconomic order which benefits the rich ones at their expense. It will open new avenues for partnership in industry and farming with mutual help and benefits in a developing nation on a more equitable relationship between capital and labour.

The agro-industry creates the pollution while producing the desired goods for profit, but is not usually interested in dealing with or even using the pollutants. If it recognizes that it is its responsibility to address such problems, it should at least build the required facilities to treat them, provided that the farmers involved take care of the operation and reutilize the byproducts as means of production such as feed, fertilizer and energy. The ideal situation is for the farmers to grow the raw materials required by the industry concerned, with much savings in transport and its allied capital, fuel and other avoidable costs, and these are the ultimate goals.

The net result should be NO EMISSION, with truly sustainable productivity, total use of all raw materials, complete recycling of all residues, self-employment and job creation, increased overall wealth for all concerned, and profitable as well as benign solutions to existing environmental, economic and social problems of development which are increasingly plaguing every country, rich and poor alike.

When considering the future, the picture cannot be more encouraging as the integrated farms will undoubtedly be the most productive and rewarding in the whole world – see below .

Their capital and operational costs are by far the lowest while the yield in all their various activities remain the highest per unit surface, area of land or water and input requirement of human or artificial energy, because of tlicir most efficient recycling of wastes to produce the feed, fertilizer, energy and raw materials required in an integrated livestock-fish-plant-processing system.

Goals of integrated farming activities

The goals of integrating livestock, fish and crop in the Integrated Biomass System are as follows:

1. Economic

The universally known problems of commercial farming in the developing world are the prohlblb costs of external inputs, such as feed for livestock and fish, fertilizer for crops, and energy for processing, while most wastes and residues are left to pollute and even degrade the environment when they should be recycled as useful resources. These problems are compounded with port technologies which are inappropriate, costly and inefficient due to the wrong systems used -uid which do not take full advantage of local climatic and environmental conditions to make the proceed more effective and less costly.

The Integrated Fanning System demonstrates that the only way for commercial farming to be viable economically is to recycle all wastes and residues as means of production for maximum productivity at lowest costs. There is no other way for most developing countries without fossil fuel, i-nlncral and other mining resources. They should capitalize on theii- sunny and hot climate for optimum microbial processes for recycling all their wastes and residues as fuel, fertilizer and feed to produce food, fibre and raw materials for economic development.

2. Ecologic

For centuries, most developing countries have followed ecological principles for subsistence and self-sufficiency from their lush forests and rich aquatic life. The same principles can be used to m,, the requirements of a m odem society, instead of adopting systems that have been designed for other climatic and environmental conditions, requiring imported and costly input such as fossil fuels al,i-ochemicals and complex equipment, and can never be economic in most of the third world.

Some developing countries were even forced to accept polluting industries to locate in their poor communities to provide lowly paid jobs, without any provision for environmental pollution control or even workers' safety. There are enough horrible examples in some countries to make the concerned leaders stop such disastrous development strategies, and adopt more appropriate systems.

The Integrated Farming System shows that modem scientific knowledge and technological innovations can improve all the farming and agro-industrial processes involved without upsetting die ecological equilibrium, and provides a new concept of development that can prevent environmental do-radadon while benefiting both investors and communities concerned, with production of foods and renewable raw materials first.

3. Social

Past development in the third world depended heavily on the strategies of the administrative powers, which used the land, people and natural resources to meet the material and industrial needs of the metropolitan nations. This development used huge areas of prime lands for livestock ranches and monocultural plantations for primary produce for export, very often at the expense of local food production. It is unbelievable that such development still continues in most countries of the third world today, and it is not surprising that they remain poor or even become poorer.

In the past, there were also many man-made cultural constraints on reudlisation of wastes in many parts of the world, with many official bodies making things worse by arbitrary laws and regulations. They resulted in many human settlements living in squalor because the wastes were not disposed of properly. Many changes have occured in recent years when the powers that be, that the only way to solve such problems is to including all the religious bodies, began to realize that the only way to solve such problems is to recycle wastes as economic resources.

The Integrated Farming System demonstrates that the developing countries can have more, viable agro-industries, with their wastes used as inputs in surrounding integrated farms, while solving the waste and pollution problems effectively and efficiently and making local enterprises highly rewarding in a healthier environment. So both industrialists and farmers benefit socially and environmentally from such collaboration. One additional aspect, whicli should riot be overlooked, the establishment of self-employment for the individual farm family with relatively small area of land and low investment which can be recovered within a couple of years, with the prospect its members becoming successful entrepreneurs as the integrated farm expands.

1.7 Waste Stabilization Ponds in Latin America,

F.A. Yanez.

CONAM,
Casilla 17078708, Quito,
Tel: +593 2 254585,
Fax: +593 2 444 992.

1.7.1 Introduction

The rapid growth of urban areas in the world, has posed an additional demand of water for domestic use, which has been supplied reducing the water resource for agriculture. As a result of this, wastewater reuse has been recognized as an important strategy for water resource conservation, mainly in arid and semi arid regions.

With this overview, developing countries have increased the use of sewage treatment plants prior to agricultural reuse. Among the treatment processes used, the Waste Stabilization Pond (WSP), has been the method most employed, due to its low costs and high pathogen removal efficiency.

However there exists a fair number of theoretical and practical discrepancies. For the most part, these are the result of lack of research on the subject and the indiscriminate use of information developed for different conditions.

Among the **theoretical discrepancies** are:

1) The inadequate use of high rate model for design of facultative ponds.

2) The second discrepancy has relationship with the reaction rate and the hydraulic submodel. Net reaction rates developed through specific tests, require the use of an specific hydraulic submodel.

   There are also deeper discrepancies on the way such constants were developed and the agreement with reality. What happens in practice with field scale ponds is that the liquid and the solids have different hydraulic submodels. For this reason, the models for BOD reduction are incomplete, because they describe the submodel for the liquid, whereas the biomass (solids) settle in the pond. This conclusion can invariably be reached after an analysis of the information on BOD removal in serial ponds. Here it can be seen that removal takes place in the first unit, being erratical in the subsequent units due to the absence of biomass, the same conclusion is reached after observing the behaviour of primary plug flow WSP, where the solids settle near the influent, exactly where the BOD reduction takes place.

The previous discussion as applies to bacterial die-off rates, reflects a serious discrepancy when such rates are calculated from inlet - outlet measurements without considering the hydraulic submodel. The common practise has been to consider the pond as a black box and assume complete mixing. This form of processing field data can lead to serious error, particularly in ponds with high bacterial removal efficiency.

3) A significant error is being practised by the use of an inadequate model for bacterial reduction, particularly for serial ponds. This subject is discussed in a following chapter of this paper.

4) Another discrepancy is the use of different design criteria for serial ponds. It has been common to design primary ponds for BOD removal and secondary or maturation ponds for fecal coliform removal. In such practise, the use of both criteria has been discontinued.

The **practical discrepancies** are the result of theoretical discrepancies, and can be classified in three groups:

1) The most adequate shape of primary and following pond units. Several designers prefer circular ponds, others square or rectangular.

2) Location of inlets and outlets for various ponds. Practised designs are: submerged inlets at the center, multiple inlets and outlets, in opposite corners, etc.

3) The existence or absence of thermal stratification and how to avoid its negative influence.

The research studies were conducted by the Panamerican Center for Sanitary Engineering and Environmental Sciences (CEPIS/WHO/PAHO) at the San Juan Stabilization Pond Complex in Lima, Peru, in two main experimental phases. In general, the purpose of both phases was to try to clarify the existing discrepancies. The main purpose of the first phase was to evaluate a series of WSP working under a variety of load conditions in order to develop local design criteria. The second research phase was conceived and conducted with more specific purposes: to study the reduction of enteric pathogen organisms and indicators through a series of WSP systems, the study of pond hydraulics trough tracer tests and the development of net die-off bacterial constants.

Other important investigations were conducted in other countries (Brazil, Jordan, Chile, etc.), so that it can be stated that in the last two decades, developing countries with the assistance of important International Organizations, have taken the leadership in research on WSP and in the development of new tools for its design, particularly for under tropical conditions. The present paper describes some new developments along this lines.

1.7.2 Quality criteria on waste water reuse

Of all the wastewater characteristics, the most important in relationship with public health aspects of reuse are the concentrations of parasites and enterobacteria. This is particularly true for developing countries, where the densities of parasites and Salmonellas are on the order of 2000 per 100 ml., whereas in sewage of industrialized cities they are practically nonexistent, (1).

The knowledge of the bacteriological characteristics is of fundamental importance in the selection of wastewater treatment processes, due to the fact that it is well established that conventional treatment processes are inefficient in removing helminth eggs, (2). Another report (3) confirms this with, evaluation data from the extended aeration plant of Jerash and the activated sludge plant of Salt in Jordan, where it is stated that such plants are deficient in removing helminth eggs. On the other hand there is conclusive evidence that WSP are adequate in removing parasites and enterobacteria, (2).

The WHO Guidelines on Wastewater Quality for Agricultural Reuse (4), indicate the levels of fecalconforms and intestinal Nematodes recommended for three types of agricultural reuse. The importance of this contribution to public health should be emphasized, due to the fact that the recommendations have direct relevance with the high morbi-mortality indices in most developing countries. In can be seen that for the reuse categories which imply human or animal consumption of crops irrigated with waste waters, the recommended levels of Nematodes are zero for practical purposes.

The adoption of Quality Standards for Domestic Wastewater Reuse for Agriculture, by Public Health Authorities will surely have a dramatic impact in the selection of treatment processes, since in most instances conventional technologies will not be reliable.

1.7.3 Evaluations of waste stabilization ponds

1.7.3.1 BOD Load limit for facultative ponds

During the first phase of the study, BOD loads ranging from 200 to 1200 (Kg/(Ha.day)), were applied to four ponds. The applied loads were correlated to NH3-N determinations in inlets and outlets, according to the following equation valid for 20 °C:

$$Y = \frac{La}{57.188 + 0.84 * La}$$

where -Y- is the fraction of NH3 -N leaving the ponds and -La- is the applied BOD load (Kg/(Ha.day)). The correlation was developed from 40 observations and has a high correlation coefficient of 0.9727. Two important characteristics are attributed to the previous finding: first a more rational criteria for definition of the limit between facultative and anaerobic ponds. The solution of the previous equation for Y = I gives a load La = 357.4 (Kg/(Ha.day)). Having in mind that NH3-N can increase in a biological reactor only through anaerobic processes, the indicated load establishes the limit between facultative ponds (with predominantly aerobic processes), and anaerobic ponds. The second aspect relates to the use of the previous criterion to other temperature conditions. With appropriate substitutions of. flow, area, concentration and volume, the load La is directly proportional to detention time R. The proposed temperature dependency relationship is:

$$Lam = 357.4 * 1.085^{T-20}$$

where -Lam- is the maximum applied BOD load (kg/(Ha.day)) for a facultative pond, at a temperature -T- (°C).

A comparison of this equation with the equation developed by McGan-y and Pescod from data of 143 different installations is shown in Figure No. 1, indicating close agreement. The previous equation is useful for the design of primary ponds in developing countries when the relationship of air and water temperature is known. Lower loads and thus smaller areas are obtained using such an equation due to the fact that in tropical climates, the water temperature remains higher than the air temperature, even during the coldest months.

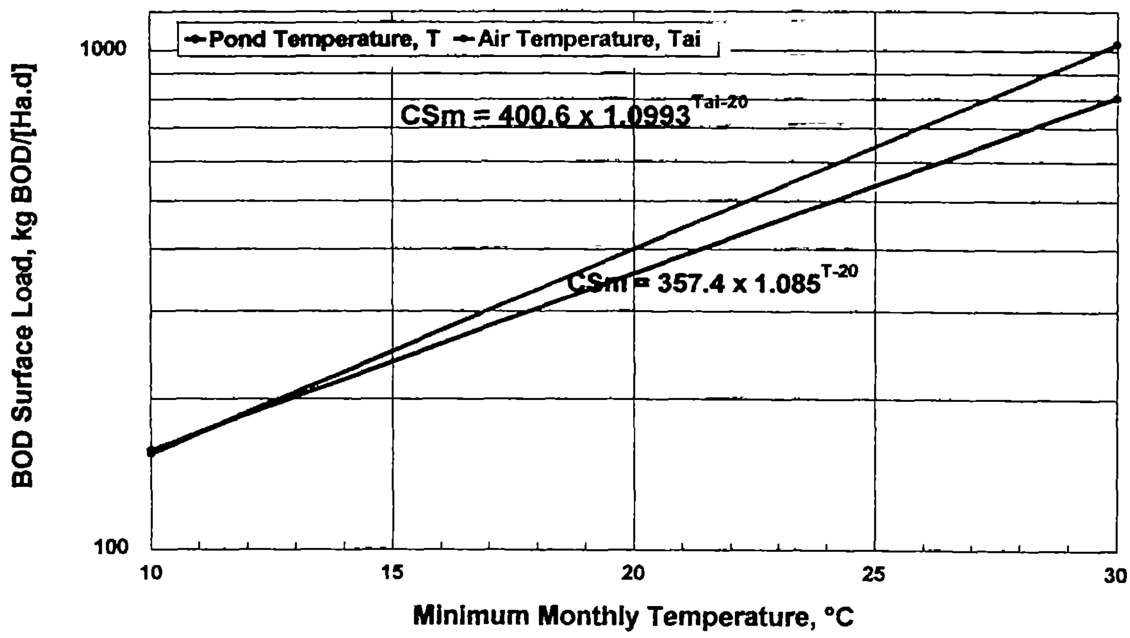


Figure 1: Maxiumum BODsurface load possible in facultative ponds.

Attention is paid to the design of facultative ponds following highly loaded primary units which can be anaerobic or aerated ponds. The loading for a facultative pond should be selected depending upon the type of primary unit and whether the effluent BOD is in the soluble or particulate matter state. The effluent from highly loaded anaerobic ponds is mostly in the dissolved state and in addition it contributes with colour typical from the anaerobic process, so that the conditions for photosynthesis are somewhat impaired. In this case all the organic matter is exerting oxygen demand immediately and little opportunity is there for sedimentation of solids. For this conditions the facultative loading may presumably be lower than for a normal facultative pond.

For facultative ponds following aerated lagoons, the situation is more favourable. The effluent from aerated WSP has organic material in the particulate state and settles to the bottom. The settling takes place within 1-2 hours, during this period the oxygen demand is supplied by photosynthesis or air-water interface transfer, consequently the load for a facultative pond will be determined by a number of factors which have relationship with the oxygen resource balance in the pond.

1.7.3.2 Removal of parasites and bacterial die-off

A literature review on parasite removal in WSP, suggests that the main removal mechanism is sedimentation. It is well known that protozoan and helminth eggs settle effectively during periods between 3 and 6 days and that Ancylostoma duodenale (Hookworm) and Schistosoma eggs can develop motile larva and appear in the effluent. It has been reported that the miracidia larva of the Schistosoma can not survive in motile conditions for more than 10 days (2). From the existing information, a minimum retention period of 8 to 1 0 days has been recommended for complete removal of helminths, (4), (7).

Information on fecal coliform mortality rates in WSP (1), (8), (9) indicates values completely different from those previously reported in the technical literature and that have been in use for more than a decade, (1 0). In the San Juan WSP evaluation, it was found that the average (of 3 1 tests) net die-off rate is 0. 841 (1 /day). This value is about 1/3 of the previously known value. Another set of 11 tests conducted for the WSP project of Cuenca, Ecuador, (8) indicates a value of 1.495 (l/day) for the net mortality rate. Further tests in WSP in Chile report values of 0. 903 (1/day) for the net die-off rate and a temperature dependency factor θ = 1.07, (9). It can be concluded that where specific die-off tests have been conducted, the results are well below the commonly used values. A summary of net die-off rate found in recent evaluations is presented on Table No. 1.

Table 1: Summary of fecal coliform net die-off rates in waste stabilization ponds.

Research:	Temperature (°C):	Kb, (l/day):
San Juan, Lima, Peru, 1982	20	0.841
Cuenca, Ecuador, 1987	20	1.485
Several sites, Chile, 1988	20	0.936
Al Samra, Jordan, 1986	12 - 15	0.3 - 0.7

Special consideration should be given to the results of evaluations of the Amman, Jordan WSP, in view of the fact that the data serve to clarify an aspect of fundamental importance, which is the non uniformity of the mortality rate through ponds in series. A summary of data reported by Saqqer (11), shows that die-off rates for anaerobic ponds are low as compared with rates for facultative ponds and also that the die-off rates decrease with increasing loading. Having in mind that the WSP of Amman are formed by 10 units in series, it can be clearly stated that the die-off rate can not be considered it can be clearly stated that the die-off rate can not be considered uniform for all the units in the treatment train.

Previous discussion establishes the need to conduct specific die-off tests, for this the recommended procedure for its simplicity is the developed in the peruvian study, (12).

1.7.3.3 Bacterial reduction models

The following discussion has the purpose of demonstration the irrationality of the use of the complete mixing model for bacterial reduction through the utilization of the following formula:

$$N = \frac{No}{(1 + \overline{K}.\overline{PR})^n}$$

The above formula has been developed under the assumption that the mortality rate and the size of the units are uniform in the treatment train. The application of such formula has not given adequate results for anaerobic-facultative ponds in series, due to the fact that the facultative pond requires a facultative loading in order to perform as such and this is not possible with the application of the previous relationship. This is particularly true for highly loaded primary ponds followed from other treatment units of the same size. The irrational use of the above formula is demonstrated in the following analysis: a reduction of four log cycles on fecal coliform is desired, in other words N/No = 10,000, a global mortality rate of Kb' = 2.0 (l/day) is assumed. The following overall retention periods are calculated with the previous formula:

4,999.5 days with one pond
99.0 days with two serial ponds
30.8 days with three serial ponds
18.0 days with four serial ponds
7.6 days with 20 serial ponds

The previous values show the absurdity practised for over two decades, because the simple increment of pond units reduces the overall retention period by a factor of about 1000, without having improved the mortality or the hydraulic submodel.

From the information presented and the validation of the dispersion model as discussed in the peruvian research, it can be concluded that so far the dispersion model is the best available tool for describing the removal of bacteria in WSP. The application of such model is simple with the use of diagrams as those presented elsewhere (16), where programmable calculators or computers are not available. The dispersed flow model proposed for bacterial performance is:

$$\frac{N}{Ni} = \frac{4a\exp(1/2d)}{(1+a)\exp(a/2d)-(1-a)\exp(-a/2d)}$$

$$a = \sqrt{(1+4.Kb.R.d)}$$

where -Ni- and -N- are the influent and effluent coliform counts (MPN/ 100 ml), -d- is a dimensionless dispersion factor, -a- is a constant, -Kb- is the net bacterial die-off constant and -R- is the nominal detention period (defined as pond volume/flow).

The factor -d- on the indicated model, can theoretically vary from zero (plug flow) to infinity (complete mixing). However past research indicates that its range is narrow. Thirimurty (18) conducted tracer studies at the laboratory scale, using a supersaturated solution of sodium chloride and found values for -d- on the order of 0.125. Mangleson and Waters (19) conducted field rhodamine tracer experiments in three ponds at Logan, Utah, and reported average detention periods on the order of 51.5 - 62.2% of the nominal values. Also the authors conducted a series of laboratory scale experiments with ponds under different conditions. The most important conclusions were: (a) environmental factors, such as wind and temperature, have great influence in tracer studies, (b) configuration and the location of inlet and outlet structures have a significant effect in hydraulic performance of WSP, © the most important factor affecting hydraulic performance is the ratio length to width and the best performance was found for ponds with larger ratios.

The importance of increasing the distance between inlet and outlet was confirmed by Wilson (20)
through a study of the mixing phenomenon in aerated lagoons with low energy densities (0.47 - 2.29 watts/m^3). The authors reported dispersion coefficients ranging from 0.395 to 4.17. Two tracer studies conducted by Gilath (30) in a full scale WSP in Israel reported values of 1.05 and 2.5 for the same factor. The only tracer studies conducted in WSP under tropical conditions are those by Dissanayake and the present research. The dispersion factors reported by Dissanayake (17) are on the interval 0.115 -0.195. These values are low when compared with other studies. it is believed that they are underestimated. The reason is attributed to the nature of the solid sodium chloride tracer used, which dissolves in a very slow fashion.

The peruvian study reported values for the dispersion coefficient in terms of the length to width ratio of the studied ponds, the information is presented on Figure No. 2.

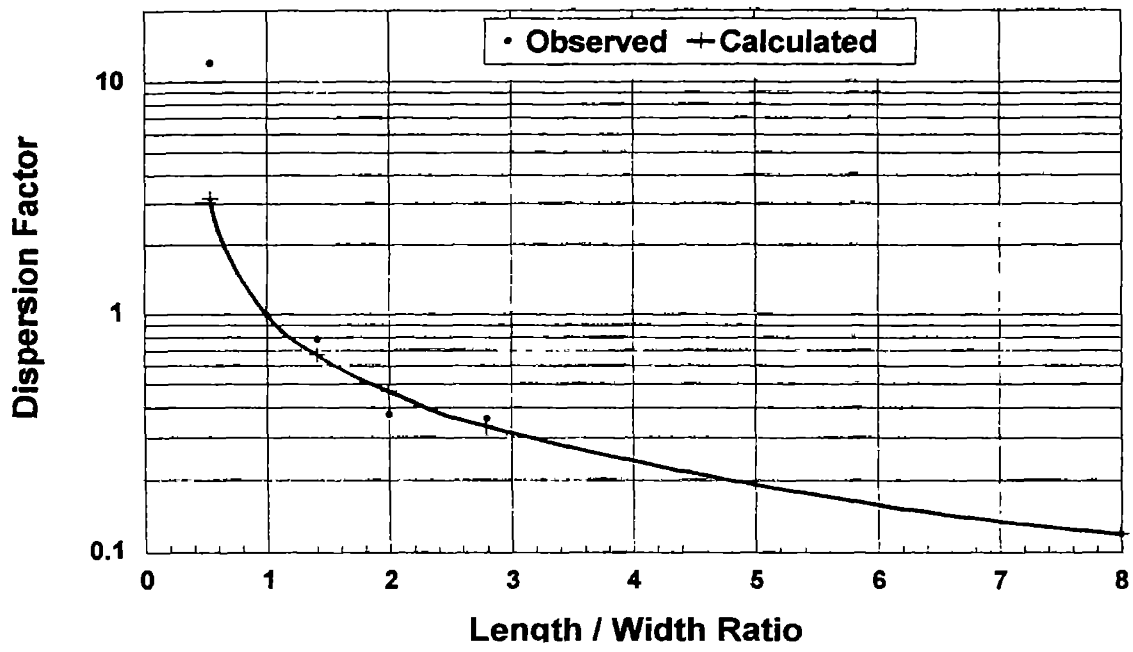


Figure 2: Dispersion factor versus shape for WSP.

1.7.4 Temperature behaviour in WSP

The knowledge of the temperature parameter if of fundamental importance in the design of Waste Stabilization Ponds (WSP), due to the fact that the mechanisms of assimilation of the organic matter and bacterial die-off are temperature dependent.For many years engineers has depended on meteorological information, for the design of WSP. Specifically the minimum monthly average temperature has been used for sizing stabilization ponds. Recent studies on temperature behaviour conducted in tropical and subtropical climates, have established that WSP gain heat via short and long wave solar radiation and that the water remains several degrees above the ambient air temperature, for the most part of the year, with lesser differences during winter periods.

Considerable information on the temperature behaviour of cooling ponds has been published in the literature of the thermoelectric industry, however in the Environmental Engineering, the procedures for calculating the temperature of WSP are few. These are described in this paper with indication of their advantages and disadvantages.

The method of conductive heath balance method is based on a simple heat balance by conduction, excluding other factors. It is exclusively limited to small ponds in non tropical climates, in lack of other more appropriate correlations or models.

Several temperature correlations have been developed from ambient-air and pond water temperature data from existing installations. therefore its use is limited to similar climatic conditions. At least four studies with continuous temperature recordings are known:

- The first study was conducted at the San Juan, Lima, Peru WSP.
- The second study was conducted at the WSP site in Melipilla, Chile.
- The third study for a warmer climate and under tropical conditions, in Campina Grande, Paraiba, Brazil.
- The fourth study conducted in the Al Samra WSP complex at Amman, Jordan.

The use of such correlations, are recommended for design of WSP in similar latitudes and climates, in absence of better information.

The model based on a complete heat balance, was adapted to take into account the following addition; parameters: precipitation, location of the site in the northern or southern hemispheres and the use of meteorological data easily obtainable in developing countries, mainly from airport meteorological stations. Additionally the model's differential equation has been solved in a simple way, a computer model has been developed in order to enable its use in an standard personal computer. The heat vector components taken into account are defined as follows:

Io = Absorved short wave solar radiation, Cal/(cm^2.day)
Is = Short wave atmospheric radiation, Cal/(cm^2.day)
Ha = Long wave atmospheric radiation, Cal/(cm^2.day)
Irs = Reflected short wave atmospheric radiation, Cal/(cm^2.day)
Har = Reflected long wave atmospheric radiation, Cal/(cm^2.day)
Hw = Long wave radiation from the water surface, Cal/(cm^2.day)
He = Evaporation heat loss, Cal/(cm^2.day)
Hc = Conduction losses or gains, Cal/(cm^2.day)
Han = Absorved long wave solar radiation, Cal/(cm^2.day)

With the previous definitions, the net heat gain or loss in a body of water -Hn-, can be calculated as follows:

$$Hn = Is + Ha - (Isr + Har + Hw + He + He)$$
$$Io=Is-Isr$$
$$Han = Ha - Har$$
$$Hn = Io + Han - (Hw + He + Hc)$$

The first five terms of previous equations are primary radiation fluxes and are of great importance in the thermal process. The remaining two depend upon the local physical conditions. The formulations for each of the heat vectors and the general equation of caloric balance is found elsewhere (16). A simplified method is used to solve the general equation of caloric balance was developed for small time intervals of 1 hour.

The calibration of the temperature model can be made with hourly data from a pond installation, the normal period taken into account is one day with different cloudiness conditions. The calibration is made by adjusting several constants of the model and mainly the cloudiness factor -C-, which is the parameter subject to personal appreciation. Calibration runs with hourly data from five installations, under different geographical and meteorological conditions has been made. The results are reported elsewhere, (12). The model has been calibrated in very acceptable conditions.

For simulation it is required as input a number of local meteorological information and other constants. The model calculates the hourly and daily heat balances -Hn-, with this value, the water temperatures are calculated. For every month the model calculates the average temperature and prints a monthly summary with minimum, maximum and average values for water and air temperatures. In the present paper, the simulation for the WSP project of Cuenca, Ecuador is presented. For this purpose, the existing hourly data from the Cuenca-Airport meteorological station were used. In the present case, the simulation started on January 1, 1986, with an assumed water surface temperature -Ts- and several runs were made adjusting the initial value until reaching agreement with the surface water temperature of the calibration day, on March 7, 1988. For the rainfall conditions it has been measured the rainfall temperature -Tp- is 2-3 °C below the air temperature -Tai- and in the present case it was adopted Tp = Tai - 3, for the corresponding rainfall period.

The average water and air temperatures for a complete year, are presented on Figure No. 3, for the Cuenca project, using the final design conditions for the year 2015, with a flow of 1.833 (m^3/s) entering to the aerated ponds (10 Ha), with a detention period of 2.94 (days). An analysis of previous results indicates that the simulation model is a valuable and tool, due to the fact that the simulated water temperature converges after a year of hourly calculations to practically the same value. From the information presented, the recommended design conditions are for the minimum monthly temperature of 17.1 °C, corresponding to the month of July. As observed in Figure No. 4, the model has been used to simulate water temperatures in a treatment train consisting of. aerated, facultative and maturation ponds. After calibration, the model can be used for simulation of the influence of different factors, such as:

- Ponds in series
- Heavy rainfalls
- Maximum flows, during wet weather periods, mainly in combined sewer systems
- Influence of other external factors, such as wind, air temperature, etc.

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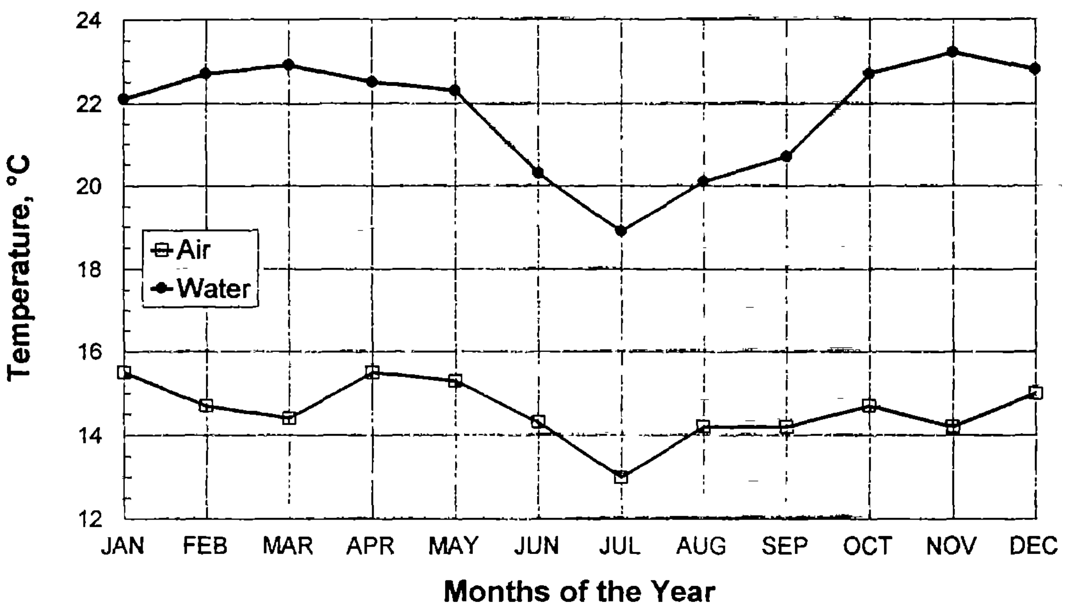

Figure 3: Temperature data for the Cuenca stabilization ponds.

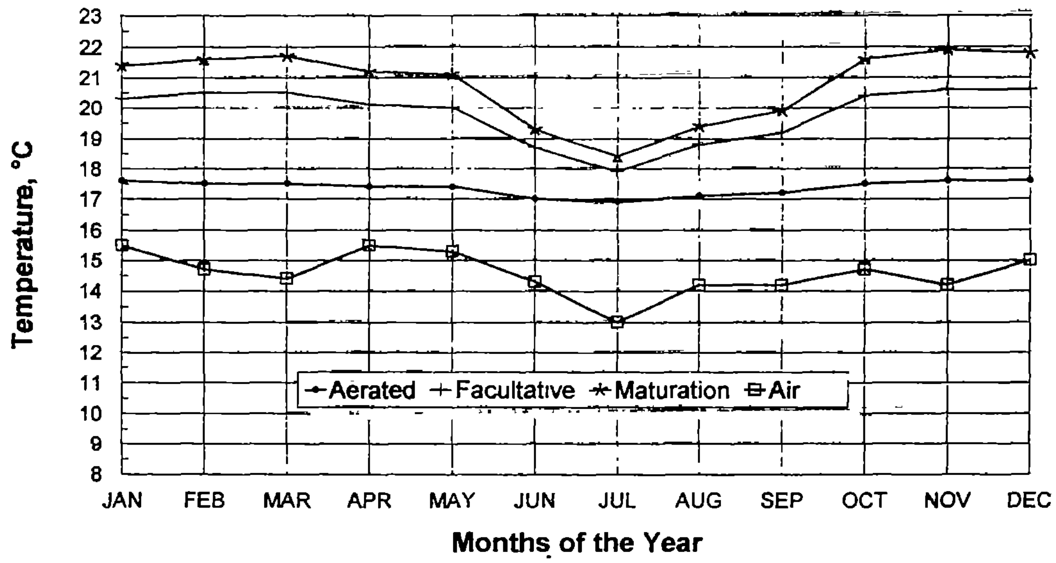

Figure 4: Temperaturs for the Cuenca stabilization pond system, year 2015.

1.8 Anaerobic wastewater treatment in developing countries, a sustainable core technology, *J.C.L. van Buuren.*

Dept. of Environmental Technology,
Wageningen Agricultural University,
P.O. Box 8129,
6700 EV Wageningen,
The Netherlands,
Tel: +31 317 483339,
Fax: +31 317 482108,
E-mail: joost.vanbuuren@algemeen.mt.wau.nl

1.8.1 Summary

Present article reviews the experiences with anaerobic treatment of wastewater especially in developing countries. It shows that anaerobic treatment technology fits well into the concept of sustainable wastewater treatment.

1.8.2 Introduction

Since the sixties of this century the field of environmental technology has been enriched by a wealth of new developments. A notable one is that of the high-rate anaerobic treatment of wastewater and wastes. Anaerobic treatment did exist before but its potential was not understood. Then existing methods were the anaerobic pond, the septic tank, the Imhoff tank and digestors for sewage sludge and animal dung.

New developments in anaerobic treatment produced a wide range of competitive and effective applications and reactor types, such as the UASB and EGSB reactor (Lettinga et al., 1984).

Anaerobic treatment methods also do very well meet criteria of sustainability.

1. Anaerobic Treatment as the core of sustainable waste treatment and resource preservation systems

Besides the usual criteria of cost-effectiveness and social acceptability sustainable technologies should meet the following sustainability criteria summarized in table 1.

Table 1: sustainability criteria for technology systems.

- Minimal use of or damage to natural, especially non-renewable, resources (including the environment)
- Minimal emission of hazardous and harmful substances to the environment
- Technical robustness and reparability
- Maximal potential for recycling and re-use of materials
- Minimal vulnerability to social and economical disruption
- Minimal environmental and health risk

The objective of environmental technology is the treatment of wastestreams, the restoration of environmental damage (e.g. soil remediation) and recycling and re-use of useful components.

In the field of the biological treatment of organically contaminated wastewater, organic slurries and solid wastes advanced anaerobic treatment methods increasingly play an important role.

In this article emphasis is laid on methods of anaerobic treatment of wastewater (AnWWT) in which anaerobic sludge bed reactors (Upflow anaerobic sludge bed (UASB) and Expanded granular sludge bed) are used.

Typical process characteristics of AnWWT are:

- the formation of highly active microbial aggregates (consortia of hydrolytic, acidogenic and methanogenic bacteria) with good settling properties,
- a good contact between wastewater and sludge which is brought about by relatively high upward flow velocities of wastewater through the sludge bed and by the mixing action of the evolving biogas.

Typical constructional features are:

- influent entrance pipes at the bottom of the reactor in a number sufficient to avoid short-circuiting and dead spaces in the reactor.
- a gas-solids-separator at the top of the reactor. The functions of this device are the smooth separation of the biogas from the liquid phase(water and sludge) and of sludge from the water phase in order to avoid sludge wash-out.

AnWWT is able to work under a wide range of conditions and research proves to be capable of more and more reducing its limitations. Lettinga (1996) indicates a temperature range of 10 - 75°C, but good results are now obtained at temperatures even lower than 10° for VFA-solutions. In research emphasis is laid on the treatment of complex wastewaters e.g. containing fats and higher fatty acids, aromatic N-compounds, aromatic aldehydes, terephtalic acid. The process of $CaCO_3$-scaling is better understood so that it can be controlled. With regard to the valorization of wastewater constituents research focusses on the integration of AnWWT with natural and high-rate microaerobic and aerobic posttreatment processes. Benefits and drawbacks of AnWWT are summarized in table 2.

Table 2: Benefits and drawbacks of anaerobic waste water treatment.

Benefits:

- Treatment can be accomplished at low costs, viz. the installations are relatively plain
- Instead of consuming energy, a useful energy carrier in the from of biogas is produced. Consequently the method does not depend on the supply of electricity or other mineral fuels.
- The method can be applied at practically any place and at any scale.
- High space loading rates can be applied in modern anaerobic wastewater treatment systems, so that the space requirements of the system are relatively small.
- The volume of excess sludge produced in anaerobic treatment generally is significantly lower as compared to aerobic systems.
- The excess sludge is well stabilized.
- Anaerobic organisms can be preserved unfed for long periods of time (exceeding one year) without any serious deterioration of their activity, while also other important characteristics of anaerobic sludge generally remain almost unaffected, e g. the settleability.
- The method can lead to the application of integrated environmental protection systems, e.g. it can be (in principle) combined with post-treatment methods by which useful products like ammonia and sulphur can be recovered, whil ein specific cases effluents and excess sludge could be employed for irrigation and fertilization or soil conditioning

Drawbacks:

- Due to the low growth-rate of methanogenic organisms start-up may take a relatively long timespecially when no appropriate seed sludge is available
- Acetogenic and methanogenic organisms are susceptible to growth inhibition by xenobiotic substances
- In most situations AnWWT needs a post-treatment stage as nutrients and pathogenic organisms are little removed

Most of the items mentioned in table 2 refer to a comparison between anaerobic and aerobic wastewater treatment methods. Lettinga (1996) concludes that the drawbacks of anaerobic treatment will virtually vanish in the near future, so that anaerobic treatment merely offers advantages over conventional aerobic treatment. Anaerobic methods are worthy to play a predominant role in wastewater treatment and resource recovery. This fact however is not always recognized.

On the basis of its intrinsic characteristics anaerobic methods can be considered a core technology in recycling and reuse systems in the field of organic wastewater and wastes.

Figure 1, in which the valorization of water and waste components is the point of departure, points out the central place of anaerobic technologies (treatment and digestion) in the sustainable treatment of low- and high-strength organic wastes.

In the anaerobic first treatment stage a distinction is made between wastewater treatment and digestion. The term treatment is used for diluted and relatively easily biodegradable wastestreams and digestion for more concentrated and poorly biodegradable wastes. In anaerobic digestion a distinction is made between slurry digestion (e.g. liquid manure) and dry digestion (e.g. municipal solid waste).

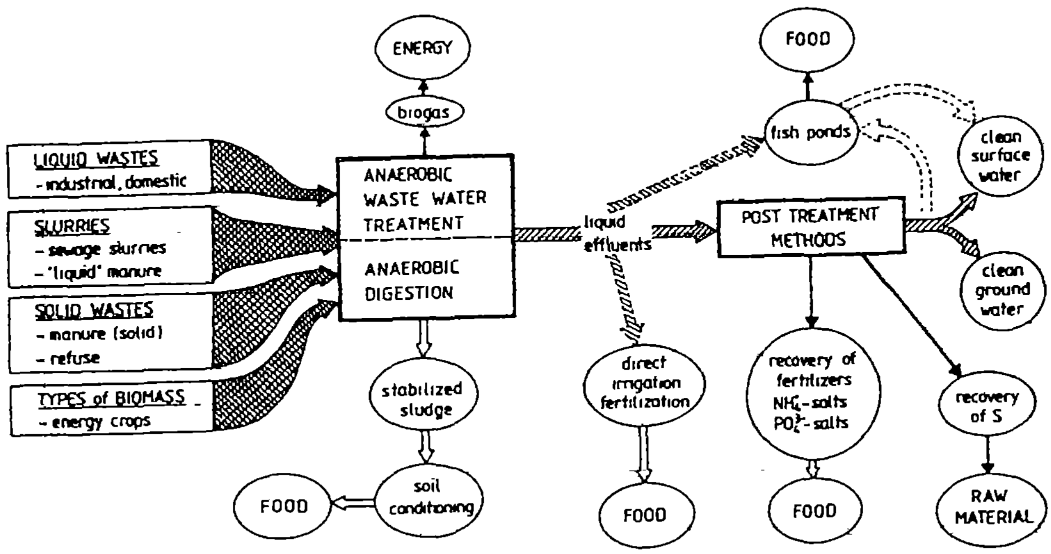

Figure 1: Sustainable waste and wastewater treatment concepts (Hulshoff Pol and Lettinga(1986)).

In anaerobic processes organic matter from the wastestream is converted to biogas (60-80% methane) and a well stabilized sludge. The methane production potentially amounts to 0.35 Nm^3/kg COD converted. The COD conversion efficiency may achieve a value of 90% in readily biodegradable wastewaters such as brewery wastewater. The economic feasibility of biogas utilization increases with the strength and the flow-rate of the wastewater treated. In the anaerobic stage only marginal percentages of N, P and S are removed from the water phase, so that these components can be utilized. Treated municipal sewage can be reused as irrigation water, as a feed to duckweed (cattle and poultry fodder) and fish ponds. In the reuse of sewage effluents special attention has to be paid to hygienic risks as pathogens are only partially eliminated.

From certain wastestreams it can also be feasible to recover N, P and S compounds. NH_4^+ may be stripped from wastewater and processed to fertilizer.

In the anaerobic treatment stage sulphate is reduced to sulphide.

By means of micro-aerobic posttreatment sulphide can be oxidized to elementary sulphur which can be recovered from the effluent. (Jansen, 1996).

1.8.3 Applications of Anaerobic Wastewater Treatment

Here, examples will be given of the application of AnWWT technology to several types of wastewaters under a wide range of conditions. Special emphasis is laid on the implementation in developing countries.

1.8.3.1 Anaerobic treatment of industrial wastewaters

High-rate anaerobic treatment processes have found a wide implementation in food and agriculture-based industries in many places in the world. In developing countries the process is applied in a.o. sugar and potato processing and alcohol distilleries, breweries, pulp and paper factories, latex rubber industry, tanneries, etc. In industries presently 914 anaerobic installations are installed (38% of installations in food industry and 25% in breweries). 67% of these installations are of the UASB type (Paques, 1996). The benefits of high possible loading rates (up to 35 kg COD/m^3.day), methane production, low excess sludge production, make themselves felt most strongly where wastestreams are relatively concentrated and easily biodegradable. Typical features of high-rate AnWWT are the formation of granular sludge with excellent settling characteristics so that high upflow velocities and short hydraulic retention times can be maintained. A high upflow velocity leads to a rapid mass transfer between water and the sludge particles.

1.8.3.2 High-rate anaerobic methods for off-site sewage treatment

Anaerobic ponds is a well-known method for off-site sewage (pre)treatment in tropical and subtropical developing countries. Characteristic features of this method are an HRT of 1.5 - 6 days, a depth of 2 - 4 m and horizontal flow.

The treatment processes taking place in ponds such as sedimentation, sorption, and anaerobic biological conversion are carried out in a more controlled, efficient and environmentally acceptable way in anaerobic reactors, e.g. in Anaerobic Sludge Bed (ASB) reactors. Pilot-plant and full-scale investigations on the treatment of sewage in ASB systems in several countries (notably in Colombia, Brazil and India) have shown that high-rate methods are very succesfull in sewage treatment.

Between 1982 and 1989 a 64 m^3 pilot-scale UASB reactor was extensively tested in Cali (Colombia) (Haskoning, 1985). In figure 2 the layout of this reactor is schematically shown.

On the basis of the design criteria confirmed in that research full-scale UASB reactors were constructed and taken into operation in a.o. Bucaramanga (Colombia) (Schellinkhout,1994) and in Kanpur and Mirzapur(India)(Haskoning,1993). Results regarding the Bucaramanga and Kanpur WTP are presented here, since these plants have been extensively monitored and are considered representative cases in tropical countries.

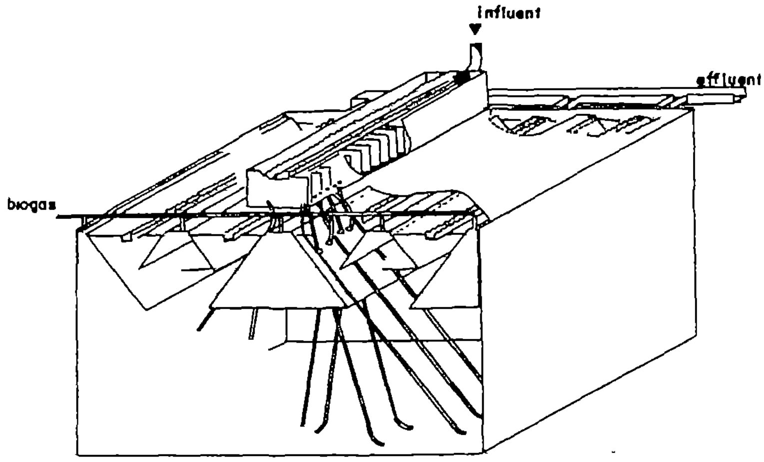

Figure 2: Schematic representation of 64 m³ pilot plant UASB-reactor tested in Cali Colombia.

The Rio Frio plant at Bacuramanga comprises the following stages:

- flow control
- coarse and fine screens
- grit chamber
- UASB reactors (parallel)
- facultative ponds
- sludge drying beds

At the Kanpur demonstration plant the same elements are found except the facultative post-treatment ponds. In Kanpur no post-treatment is provided.

Table 3: Characteristics of the UASB reactors in Bucaramanga and Kanpur (* BOD removal of UASB + post-treatment pond (HRT 1.7 d)).

		Bucaramanga (Colombia)	**Kanpur** (India)
Dry weather flow rate	(m^3/d)	31,000	13,000
Influent BOD	(g/m^3)	160	210
Influent TSS	(g/m^3)	240	420
Temperature range	(°C)	23-25	20-30
HRT (average)	(hrs)	5.2	6.0
HRT (peak flow)	(hrs)	3.5	2.4
Reactor height	(m)	4	4.5
Inlet points	($\#/m^2$)	0.35	0.25 and 0.50
BOD-removal	(%)	75 (85*)	80
TSS-removal	(%)	91	75

Table 3. presents some of the design criteria as applied to the UASB-reactors in these two plants.

Figure 3 shows the development of the BOD and COD treatment efficiency of a UASB type sewage treatment plant.

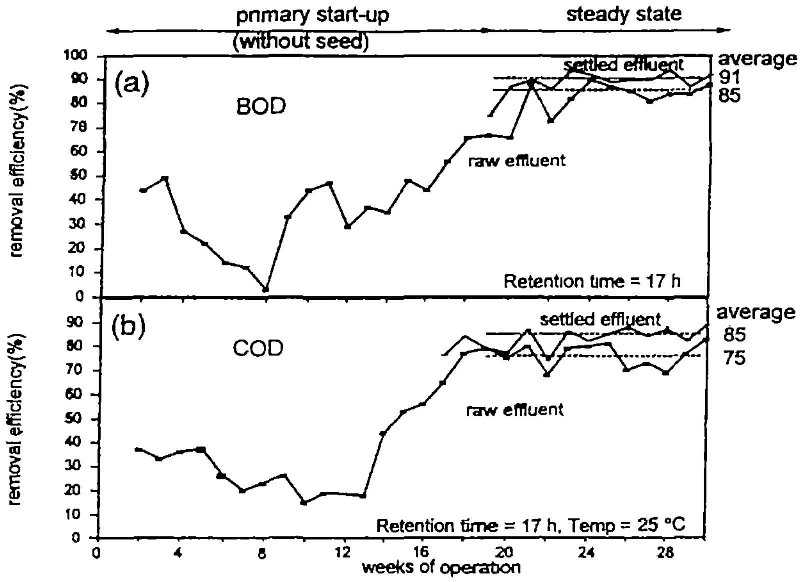

Figure 3: Evolution of (a) BOD and (b) COD removal efficiencies in a UASB-reactor treating raw sewage (Van Haandel and Lettinga (1994)).

Operation and maintenance experiences in sewage treatment:

■ *Start-up*

If seed sludge is available UASB reactors could be inoculated to 20% of their volume. But in Bucaramanga and Kanpur the reactors were started without inoculum.

In the first weeks after start-up loading was somewhat lower than the design load. In both cases loading was interrupted for some

time during the start-up period in order to restore the settling properties of the sludge. Normally after 2 to 3 months the reactors can handle well their design load. In Bucaramanga steady-state performance of 75% BOD removal was achieved after about 6 months of operation.

■ *Regular use*

The UASB reactor experience has generally proven to be

successful. Problems encountered thus far are related to the mechanical pretreatment (screens), electrical equipment and corrosion of concrete used for tank construction and other appliances on the site of the WTP. Schellinkhout (1994) calls for attention to the quality of the concrete and its coating. Hulshoff Pol recommends the use of plastic gas collectors (Hulshoff Pol, 1996). For breaking up scum layers a small compressor can be used (Bucaramanga)

■ *Post-treatment*

Usually anaerobic treatment alone is not sufficient to meet effluent re-use or discharge standards and a post-treatment stage is required. The most obvious and least expensive option in most cases are stabilization ponds. The design loading rate adopted will depend on the treatment objectives. In Bucaramanga the posttreatment pond was designed at a loading rate of 500 kg BOD/ha.d and a depth of 2 m leading to an HRT of 1.7 days.

NH_4^+ and PO_4^{3-} can be valorized by using the anaerobic effluent (with or without further treatment (pathogens!)) for irrigation.

If land is not sufficiently available more compact high-rate systems are necessary. System choice will depend on local possibilities and requirements. Promising high-rate post-treatment methods seem to be biorotors and aerobic/anoxic activated sludge systems (Van Buuren (1991), VROM (1991)).

■ *Energy balance*

In anaerobic treatment biogas is produced that can be used as fuel. Schellinkhout (1994) mentions a typical gas production of 60 l/m^3 sewage treated. For a WTP in Mirzapur (Q = 14,000 m^3/d, influent BOD = 180 gr/m^3) an average biogas production of 500 m^3/d (80% CH_4) is expected yielding approximately 70 kW, while the power requirement of the plant is 12 kW.

Methane gas discharge to the atmosphere strongly contributes to the greenhouse effect. Therefore biogas should not be discharged but be used as fuel or flared at the site.

■ *Sludge disposal*

In off-site sewage treatment the excess sludge production from UASB reactors amounts to 0.3 - 0.4 kg TS/kg TSS present in the influent. The excess sludge has excellent dewaterability characteristics and can be applied to simple sludge drying beds at a rate of 10 kg TS/m^2.wk. This implies that the area of the sludge drying beds can be relatively small.

■ *Costs*

Oomen and Schellinkhout(1993) made a cost comparison (investment plus O&M) of 9 sewage treatment systems for tropical conditions

(cold weather water temperature > 15° C).

Among these were conventional aerobic systems, aerated ponds, stabilization ponds and UASB treatment having either a trickling filter or facultative ponds as a post-treatment stage. They showed that the annual costs of the latter system were the lowest under a wide range of conditions. Stabilization pond systems were cheaper when land costs were less than about 14 USD/m^2.

Under the conditions of a 90% BOD removal efficiency, a T = 25° C, a land cost of 20 USD/m^2 and a scale of 50,000 p.e. the annual costs of a UASB pond system amounted to about 4 USD/p.e, while the costs of an activated sludge system were about 8 USD/p.e.

Ongoing developments

Presently several new full-scale UASB type reactors are under construction, have been commissioned recently or are already operating for several years. New reactors will e.g. be built in India in the framework of the Yamuna Action Plan in India (7 plants for flow rates ranging from, 10,000 - 45,000 m^3/d), in Venezuela (Puerto Cruz and Quanta), Ecuador (Babahoyo). Also other reactor types for sewage treatment have been developed and tested with favourable results such as the upflow anaerobic pond, the anaerobic plug flow reactor (RAP) and the two-stage Upflow Anaerobic Sludge Retention (UASR)- Expanded Granular Sludge Bed (EGSB) system.

1.8.3.3 High-rate anaerobic methods for on-site wastewater treatment

The septic tank (ST) is one of the well-known methods in on-site treatment of sewage. The processes occurring in septic tanks are basically the same as in the anaerobic ponds: settling of suspended matter, anaerobic conversion of organic matter and accumulation of sludge. Typical design criteria are: HRT 3 days (of which a 2 days volume is destined to sludge accumulation, depth 1 - 2 meters, horizontal flow). Often ST are devided into two or more compartments to avoid short-circuiting and to obtain a quiescent zone at the outlet.

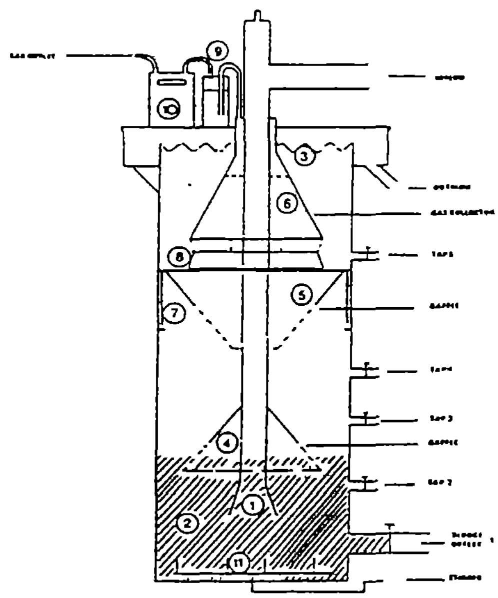

Figure 4: Research upflow septic tank used in Indonesia.

In a couple of research projects the design principle of the UASB, i.e. upward flow and gas/solid/liquid separation at the top of the tank has been applied to the septic tank.

The first project was carried out in Bandung(Indonesia) between 1984 and 1991. Here the treatment of both black and combined black and grey water were studied (IHE/WAU/St Borromeus Hospital, 1991). The second project took place in the Netherlands working at research locations in Bennekom, Kootwijk and Noordwijk in 1987 and 1988 (Bogte et al., 1993).

■ Experiences with the UASB septic tank in the tropics

A cross-section of the reactor (0.86 m^3) used in the Bandung study is shown in figure 4.

❑ *Black water treatment*

In the black water studies the influent came from 2 pour-flush toilets used by 9 persons.

Typical data and results are presented in table 4 and 5.

At start-up the reactor was seeded with 166 l of septic tank sludge. The system performed well from the start until the moment sludge was carried over with the effluent due to complete filling of the reactor. Both suspended and soluble organic substances were removed to a high extent (see table 4). Nitrogen and phosphorus are not removed. Average effluent concentrations of these substances were 300 - 500 gr/m^3 (N_{tot}) and 40 - 50 gr/m^3 (P_{tot}). The average removal of helminth eggs was 95%, which is considered satisfactory. Faecal coliforms were poorly eliminated producing a 10^7-10^8/100 ml count in the effluent.

Sludge accumulated in the reactor filling it to 76% of its volume after 731 days of operation. The dry matter content of the sludge ranged between 50 and 70 kg TS/m^3. The methanogenic activity of this sludge was 0.1 - 0.2 kg CH_4-COD/kg VSS.d at 25 - 30°C. and it had a good stability: only 10- 17% of sludge COD could be converted to CH_4 after 100 days at ambient temperatures.

Biogas production was rather constant at a value of 5 - 6 l/hr (65% CH_4).

Table 4: Data and results of the Bandung studies on treatment of black water and sewage with an UASB-type septic tank.

		Black water treatment	Raw sewage treatment
Flow-rate	(l/d)	50-100	489 ± 199
Influent COD	(g/m^3)	5,542	1,359
Influent BOD	(g/m^3)	1,586	387
Influent TSS	(g/m^3)	1,803	274
Temperature range	(°C)	22 - 25	22 - 25
HRT	(days)	8 - 17	1.25 - 2,97
SLR	(kg COD/ kg VSS.d)	0.12	0.02
Reactor height	(m)	1 8	1.8
Inlet point		1	1
COD-removal	(%)	90 - 93	67 - 77
BOD-removal	(%)	86 - 95	46 - 78
TSS-removal	(%)	93 - 97	74 - 81

Table 5: Design and operational criteria of UASB-type septic tank treatment of blackwater and sewage.

Parameter	Black water	Sewage
Reactor volume (m^3/i c)	0.12	0.15
Height (m)	2	2
Seed sludge (% reactor V)	10	10-15
Max. reactor filling (%)	90	90
Excess sludge production (l/c d)	0.08	0.08
Emptying interval(years)	3.5	3 5

At the same location (Bandung) and conditions (T = 25° C, HRT = 360 hr) also a conventional ST and a ST modified to upflow behaviour (no gas collector) were tested treating blackwater ($COD_{t,inf}$ = 6 gr/l). The treatment efficiencies are compared in table 6.

It was concluded that despite considerable fluctuations in loading rates upflow-type septic tanks perform very well in black water treatment in the tropics and that further research should concentrate on two-compartment systems.

Table 6: Efficiencies of 3 ST types treating black water.

Parameter	ST (%)	Modified ST (%)	UASB-type ST (%)
COD_t	80	89	92
TSS	75	92	97

❑ *On-site Sewage treatment*

The 0.86 m³ upflow reactor shown above was also used for experiments on sewage (black + grey water). The influent was drawn from 2 pour-flush toilets used by 11 people. The reactor was seeded with 150 l of septic tank sludge (TSS: 48 kg/m³).

Treatment efficiency was lower than in the black water experiments but improved gradually during the first year of operation and after a year a rather steady 80% BOD and TSS removal was attained. After 769 days of operation the sludge bed had reached a height of 133 cm. The stability of the accumulated sludge is considered satisfactory.

The design and operational criteria drawn from this study are summarized in table 5.

Both in black water as in sewage treatment a gradual accumulation of solids take place. This sludge is well stabilized.

Experiences with the UASB septic tank at low temperatures

The performance of the UASB-type septic tank was also studied under more adverse conditions (lower T and more dilute wastewater) in the Netherlands at locations in Noordwijk (sewage), Kootwijk (sewage) and Bennekom (black water).The Reactor volumes were 1.2 m^3 .(Bogte et al.(1993).

Table 7: Conditions and average treatment efficiencies of UASB-type septic tanks tested in the Netherlands (after: Bogte et al, 1993).

	Blackwater (Bennekom)	Sewage (Kootwijk)	Sewage (Noordwijk)
Specific volume(m^3/i.e.)	0.12	0.42	0.42
Influent COD_t (gr/m^3)	1,720	821	976
Influent BOD (gr/m^3)	640	467	454
Temperature range (°C)	8-16	8-18	10-18
HRT (hrs)	102.5	57	44
COD-removal (%)	60	4	31
BOD-removal (%)	50	15	38

The work by Bogte et al. shows that treatment efficiency strongly depends upon reactor temperature (T). The BOD removal taking place at temperatures below 12° C was merely based on settling and thus much influenced by turbulence. At temperatures between 8 and 12° C acidogenic fermentation was still active but conversion of volatile fatty acids to methane nearly came to a standstill. At temperatures above 12° C methanogenic activity increased, while complete conversion of VFA to CH_4 was achieved at 15° C and higher.

In the Noordwijk tank during the warmest part of summer (T =15-18° C) a part of the organic matter accumulated previously during winter time was converted to biogas, so that BOD removal efficiency temporarily reached values higher than 100% (See figure 5).

Overall COD and BOD treatment efficiencies during the 2 year's test period were 31% and 38% respectively.

In the Kootwijk reactor efficiencies were low probably due to frequent strong turbulence caused by maintenance activities. The Bennekom reactor that treated black water showed reasonable COD and BOD removal efficiencies more based on accumulation of sludge in the reactor than on conversion to methane.

Figure 5 also shows that considerably better treatment performance was achieved 16 months after start-up in the second year of operation. Unfortunately after two years the experiments had to be concluded so that the long-term performance of the UASB-type septic tank under conditions of a temperate climate as yet remains a promise.

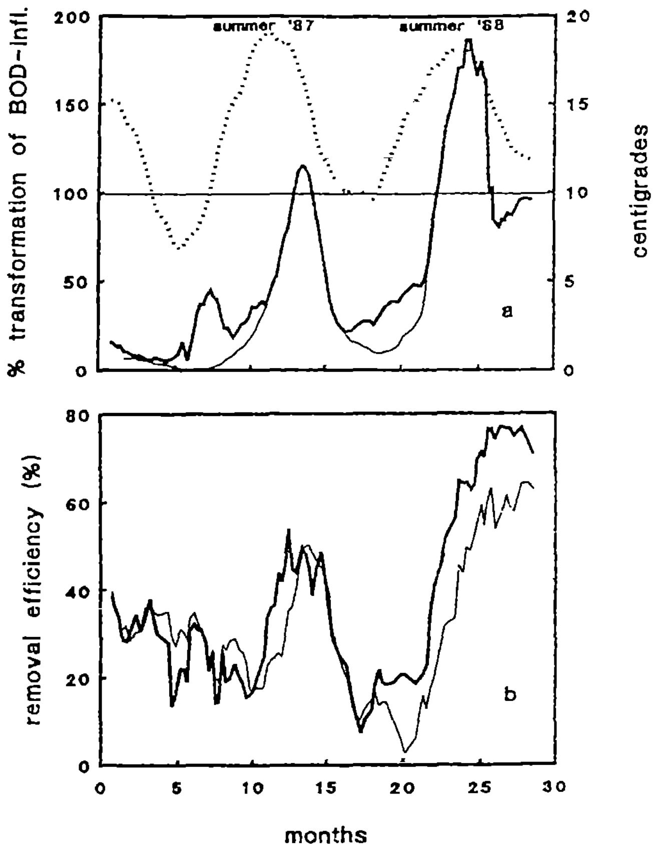

Figure 5: Performance of UASB-type septic tank treating sewage
a) Reactor temperature and relative conversion of BOD_{inf} into $VFA+CH_4$ (—) and CH_4 (—),
b) Removal efficiencies of BOD_t (—)and COD_t (—).

1.8.4 Conclusions

Anaerobic methods based on the upflow sludge bed principle have developed to a technologically reliable and economically attractive wastewater treatment technology capable of treating low, medium and high strength wastewater containing soluble and to some extent also particulate compounds in a temperature range between 12 and 70° C.

In order to still widen the range of application research on AnWWT at the Wageningen Agricultural University focuses on the treatment of industrial and domestic wastewater under more difficult conditions (high and low temperature, high particulate matter content, inhibitory substances, on-site treatment), on posttreatment processes enabling valorization and re-use of wastewater constituents and on processes involving sulphur compounds (sulphate reduction and sulphide oxidation).

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1.9 Scale of waste water treatment, *J. Rijnsburger (WASTE).*

WASTE Advisers on Urban Environment and Development,
Nieuwehaven 201,
2801 CW Gouda,
The Netherlands,
Tel: +31 182 522625,
Fax: +31 182 584885,
e-mail: office@waste.nl

1.9.1 Scale

Scale refers to the service area of waste water treatment. It refers to the number of people (capita), or households (families), or housing units (concessions) producing waste water, within a geographical delimitation, which is treated within that area or, at a distance, specifically for that area.

The following scale levels we found in our work in African cities. These findings are not based in scientific research, but on practical experience in project execution in waste and sludge collection. Two are rather clear, the scales for on-site sanitation:

- The ***housing unit***, shared by a household or family (10 - 40 p) sharing a housing unit or concession. This is the scale for on-site treatment, where you find latrine pits and sometimes septic tanks
- The ***housing block***, where 4 - 10 households (40 - 200 p) as neighbours share an on-site treatment facility, almost in principle a septic tank.

The following are less easy to define in terms of numbers, but have more to do with the entity of the geographical delimitation:

- The ***neighbourhood***, where a social tissue and joint interests are the basis for a community effort to improve conditions, either in the upgrading of the on-site facilities, or in the organisation of waste water collection (100 - 2000 p).
- The ***quarter*** (10.000 - 20.000 p), the planners' delimitation of areas where a coherent set of infrastructure like a sewer network in the roads and a treatment plant are planned for.
- The ***municipality*** (100.000 - 500.000), the political entity where the decision making and sometimes the physical planning of waste water treatment takes place.
- The ***metropolitan area*** (>1.000.000), the conglomerate of municipalities which often have a coordinative authority which make the regulations and standards for waste water treatment, or even design, operate and maintain the actual treatment of waste water.

In terms of the number of population serviced and volume of waste water treated this is the range between small scale and large scale treatment, which has parallels in talking of on-site versus off-site treatment, as well as decentralized versus centralized treatment.

Currently, in Bamako, Mali, a discussion has emerged between partners (GIE, Mairie, experts) involved in the sanitation upgrading of Commune IV, on the choice of planning for either one communal treatment facility for all of Commune IV, or several smaller facilities at the neighbourhood scale. For making choices on the scale level for waste water treatment, I have the following considerations, neither of them directly related to the treatment itself, but rather to the system treatment makes part of, and to the nature of the waste water generated at households.

1.9.2 System elements

The typical system elements, in terms of infrastructure, related to waste water treatment are:

- the ***on-site storage*** facility at the household level
- the ***transfer*** facility in between the household storage and disposal
- the 'end of pipe' ***treatment*** facility before disposal
- the ***disposal*** itself.

These system elements can be found in the three types of waste water systems which can be found:

- conventional sewerage system
- small bore sewerage system
- pit sludge emptying system.

The difference between these three system is rather visible in the transfer element (sewers versus tankers), but it also exists in the on-site storage and treatment elements.

1.9.3 The nature of waste water

For the treatment of waste water in developing cities, the 'classical' distinction has to be made between the two types of household waste water, grey water and black water:

- grey: the waste water after washing up, laundry, bathing
- black: excreta, urine and water for anal cleansing and, in water borne systems, flushing

In the conscience and practice of many households in developing cities in the South, grey and black water are appreciated and handled differently. This is maybe linked with the, in origin rural, culture of using latrine pits. Pits are an expensive infrastructure, a high investment for the household. For instance in sandy soil conditions lining with blocks is necessary. Rocky soil conditions necessitate the labourious crushing of stone. People don't like to waste the scarce pit volume by disposing washing water, and often the washing water is disposed off separately:

- by draining the bathroom floor directly into the street (guttered or not)
- by using the washing water to irrigate plants
- by sprinkling the water over the earth road surface in front of the house to prevent the proliferation of dust.

The on-site handling of waste water at household level is the starting point of any waste water treatment system, it is the source of the waste to be treated, it defines the specifications of the waste to be treated, it defines the opportunities to involve residents and create willingness to pay for treatment, it contains knowledge of separation at source, which is an asset in strategies to reduce the volume of waste to be treated and concentrate on the specific pollutant to be treated..

These cases of Bamako and Dar es Salaam show that any strategy to improve the sanitation system and introduce treatment has to start from the households using pits and draining off their grey water separately. The numbers of demand are overwhelming (>80% of the population). Moreover, the starting point is not zero: the population already has invested in sanitation facilities, the household hygiene awareness and practise already has a tradition with its own rationales. Complementary infrastructure and services (i.e. for pit emptying) already have been developed. The existence of a given system has to be respected.

1.9.4 Aspects

The scale of treatment, and the principle dimensions of a treatment facility, cannot simply be based on the technological variables with regards to the process of the treatment method and the construction of the treatment plant. The decisions on scale have to respond to variables in all the treatment system elements as shown above: on-site storage, transfer, treatment and disposal. The on-site storage at household level is related with the ***social*** aspects of neighbourhood improvement, hygiene awareness, household traditions and willingness to pay for sanitation services. The transfer and treatment of waste water are very much related with the ***technology*** and ***economy*** of public infrastructure and services. The disposal of waste water is very much related with the ***environment*** aspects of ground and surface water pollution and disease transmission. The overall existence and sustainability of a sanitation system is related to the ***policy*** aspects of initiative, planning, financing and governance as well as the legislative context of performance standards and control.

1.9.5 Community demand

The basis for any sanitation system is the demand for its output. Often this has a private and a public component:

- it is in the ***self interest*** of a family to maintain a standard of personal and family hygiene, and protect its private resources (e.g. drinking water)
- it is in the ***public interest*** that resources of drinking water for all are not being polluted and that the transmission of diseases is being controlled both in the private (but the neighbours') and the public environment.

The information and motivation for both of the interests can be stimulated by means of hygiene education, but the extend of creating public interest is limited by the level of confidence in the relations between the public and its authorities. Sometimes a parallel structure of civic organisations is emerging which take up the cause of a territorial or cultural entity, as is the case in Bamako. A variety of initiative groups (GIE, Coop) have taken up the cause of improving the living conditions in the neighbourhoods in combining them with the search for employment and income for school leavers or women. Also these civic organisations can be plagued by a lack of confidence, but often there is a better communication and understanding due to social tissue, the involvement of elders and leaders, or the representation of the 'grassroots level' in the decisive bodies.

With regards to scale of treatment this extend of confidence is extremely important. Without information on the why and how of treatment, without consideration of the typical household outlets to transfer and treatment (system links), without ways to complain and correct a poor performance of transfer and treatment, there will be no willingness to ask and pay for treatment. In the current state of affairs in many cities this willingness is difficult to mobilize within the existing relationships of the public and its government. The scale of a civic organisation can offer a better starting point. But this means that the treatment system has to respond to the geographical or managerial extend of the civic organisation.

1.9.6 Operation of sludge transfer

Scale of treatment technology can be defined by the economy of scale of different options, with regard to the construction of the plant, and the type of treatment process to be facilitated. When the technology options respect the coherence of the treatment system as a whole, including the on-site storage, the transfer and the disposal, a different range of scale parameters have to be observed. In this article I will not go into the specific treatment parameters, but look at the parameters of the connecting system elements and their influence on scale for the system as a whole.

In the transfer of waste water a difference can be made between infrastructure that has been developed and designed for large scale application, and infrastructure that is appropriate for smaller scale application.

The large scale transfer options are:

- □ conventional sewer network, with a hierarchical grid of collectors and mains, with pumping stations to create flow and level differences in altitudes
- □ 4 - 6 m3 vacuum tankers for the emptying of latrine pits and vaults and the desludging of interceptor and septic tanks.

These transfer sub-systems are appropriate in combination with a treatment facility that is centralized (the transfer infrastructure allows long distances) and of large capacity (it serves a wide radius with many inhabitants).

The typical sub-systems designed for a limited radius of application are:

- □ small-bore sewer network, the flow of which is driven by gravity
- □ 0,2 - 2 m3 tank vehicles, for the (partial) emptying of latrine pits, vaults and soak pits.

The typical maximum radius of operation of the small emptying vehicles is 0,5 - 3 km, depending on volume and driving speed. The MAPET project in Dar es Salaam, Tanzania, showed that the handling a full 0,2 m3 push cart (oil drum size) already is at its limits over a distance of 0,5 km, and the application of 2 tanks of each 0,1 m3 would be a better option for that range of distance. Mini-tankers (as manufactured by MCA, Ireland) show an economical radius which is limited to 3 km at a driving speed of 30 km/h. The large vacuum tankers trucks, built for 50 km/h driving speed, don't have this limitation. Technically the radius can be 10-15 km between pit and disposal, but it is clear that the longer the driving distance the costly the service will be (fuel, wear, and down time). In Dar es Salaam the large tankers in practice all operate within the range of 5 km.

When planning for the off-site treatment of pit sludge which is transferred from the household by small emptying vehicles, it is imperative to respect this radius. Two options can be thought of:

- □ the 'end of pipe' treatment in small units at a grid of about 1 km for hand carts, 2,5 km for donkey carts (and its motorized equivalents) and 5 km for mini-tankers
- □ a transfer in two stages with primary and secondary collection as is the case in garbage collection, with a transfer vault to contain the continuous flow of sludge collected by the primary collection, as a buffer for the less frequent secondary collection.

A transfer in stages is an interesting option when it comes to combine the potentials of small scale and affordable pit emptying services in the neighbourhood, with a treatment facility for which the space is lacking within the neighbourhoods. However, the big constraint of transfer in stages is the technological and economical sustainability of the secondary collection. This secondary collection has to be performed by the conventional vacuum tanker trucks, for the following reasons:

- □ to hire the services of a private operator is costly and rarely covered out of the primary emptying fee
- □ to hire the municipal tanker services can be expected to be as (un)reliable as the secondary garbage collection (in Bamako and many other cities this is the big handicap of private neighbourhood collection)

- the deployment of a vacuum tanker by the neighbourhood operators themselves requires a level of technology and business management which is often beyond their capacities.

Also the operation and management of the central treatment facility can not easily be envisaged under the responsibility of small enterprises of the neighbourhood.

The other option, a small scale treatment plant per neighbourhood, better responds to the geographical and management opportunities of a neighbourhood oriented enterprise, which has its roots in the primary collection. Also it responds to the social extend of civic organisations, as mentioned above. There are very few examples of treatment plants specifically designed for the neighbourhood scale. The 'station d'épuration de Castors SOCOCIM' in Rufisque, Sénégal, is one example. It is the end of pipe treatment of a small bore sewer network, with macrophyte treatment and co-composting of the harvested water hyacinths with organic household garbage. It currently has 150 connections, serving 2.400 people, but it has the capacity of 500 connections (8.000 p).

1.9.7 Conclusion

Both the community demand and the operation of sludge transfer indicate that the treatment at the ***neighbourhood scale*** is the most appropriate to develop and to avail. Now which are the specific features of such neighbourhood based treatment:

- lack of space due to dense land use, therefore treatment has to be small, space efficient
- the community is living closely around it, so the treatment has to be safe (e.g. security for playing children) and without nuisance for the neighbours
- the grey and black water can be collected separately, so it is feasible to design for the optimal mix between pit sludge and grey water with regards to the treatment process
- the treatment process can largely be designed on pathogen removal
- their is scope to extend the private collection of sludge towards operation and maintenance of the treatment station, for this the economic benefit of a by-product out of treatment may ne crucial, not so much as the basis for financing but as the incentive for the vested interest
- there is a scope to integrate garbage treatment with sludge treatment for this economic benefit, in particular to increase the nutrient value of household compost (lack of N, enrichment of sand and dust)
- the operation and maintenance of the treatment process has to be simple and reliable, the knowledge of which has to be acquired by people that come from scavenging.

About Dar es Salaam, Tanzania

In Dar es Salaam, a city of over 2 million, 80% of the population is depending on on-site sanitation, mainly traditional single pit latrines. The habitation is for a large part unplanned. The population pressure is high, the housing is dense, the use of toilet and bathroom is often combined in one space. The pits in Dar es Salaam have to be lined because of the coral sand soil along the East African Coast. The water table varies. Dar es Salaam is situated in an estuary where half of the residential areas are well situated with respect to the water table, adequate for the proper functioning latrine pits of 3,60 m (12 feet) deep. The other half, mostly low income, has to deal with a seasonal fluctuating and periodically high water table, which is being compensated by raising the pit wall of the latrine to 1-1,5 m above the soil surface. The lined pits have a relatively high volume (6-10 m3), but due to the intensive use and clogging of the soil the leaching capacity reduces and after 2-5 years periodical emptying of the pit is necessary: it has become a vault. To prevent untimely overflowing of the pit, the washing water often is drained off separately in a corner and disposed outside the dwelling in the public space. For pit emptying the residents have to hire vacuum tanker services, in areas where these have no access manual emptying occurs (traditional and improved: MAPET, a neighbourhood based small enterprise service) with on-site burial of the extracted sludge. The space for burial is often constrained, the incidence of a high water table prohibits the burial as an adequate option for disposal. The vacuum tankers dispose the sludge in one of two sewage treatment systems, for the purpose of which two preceding anaerobic reception basins have been added to the conventional pond system.

About Bamako, Mali

In Bamako, a District with 6 municipalities of in total 1 million population, the household sanitation is almost fully on-site. In Commune IV 86% of the population is depending on traditional single pit latrines. Being situated along the river Niger the soil is partly argyle, partly rock. Pits do not have to be lined but the digging is through rock is hard and expensive. The argyle condition often includes a high water table (water flow towards the river bedding). With the use of a pit the washing water is disposed separately on the road surface or in the drains (canivaux). The typical improvement of on-site sanitation in Bamako is the construction of water tight vaults (fosses étanche) for the disposal of excreta, and the construction of soak pits (puisards) for the disposal of washing water. For the emptying of pits, vaults and clogged soak pits, the residents have to hire vacuum tanker services (Spiros). Traditional manual emptying with burying in the road reserve does occur. As an extension of their strong involvement in the primary collection of household waste, some small enterprises (GIE) have begun to offer services for pit emptying (vidange), with equipped with a donkey cart and a diaphragm hand pump. The disposal of both vacuum tankers and donkey carts is in the open air on an empty piece of land: there are no facilities for disposal and treatment in all of Bamako.

1.10 Treatment of sludges from non-sewered sanitation systmen, *Martin Srauss.*

SANDEC,
EAWAG, Ueberlandstr. 133,
8600 Duebeadorf, Switserland,
Tel: +41 1 8235399,
Fax: +41 1 8235020,
E-mail: strauss@eawag.ch

1.10.1 The challenges of faecal sludge (FS) disposal and use

1.10.1.1 Urban Excreta Disposal: Situation and Issues

The excreta of the majority of those urban dwellers in developing and newly industrialising countries which avail of some type of excreta disposal system are disposed of through **on-site sanitation systems** such as **private and public latrines**, **aqua privies** and **septic tanks**. Fig. 1 schematically depicts the types of excreta disposal systems mostly used.

In contrast to this, in industrialised countries[1], excreta are disposed of via cistern-flush toilets, city-wide sewerage systems and central wastewater treatment works all of which constitute standard technology used in urban and semi-urban areas . Fig. 2 illustrates the two contrasting situations in a schematic manner. In the majority of the cities in developing or newly industrialising countries, faecal sludge (FS) disposal, i.e. collection, haulage and treatment, constitutes an unresolved problem. The situation is likely to persist in most cases for many years to come.

In many cities, haulage distances to outlying treatment or disposal sites are excessive and traffic congestion prevents efficient emptying and haulage of FS. The sludges are therefore dumped untreated at the shortest possible distance, be it on open ground, into drainage ditches and water courses, or into the sea. Growing urbanisation and the concurrent spreading of on-site sanitation systems lead to an increase in faecal sludge quantities to be disposed of. Septage and nightsoil are properly treated in treatment plants designed for this very purpose only in a few cases (e.g. in Ghana and Indonesia). In some countries (e.g. in Botswana, Tanzania, South Africa), FS are added to the urban wastewater stream for co-treatment in wastewater treatment plants, generally waste stabilisation ponds (WSP). These are in many cases overloaded and suffer from malfunction for lack of adequate operational measures, monitoring and maintenance. In China, the traditional excreta disposal practice consists in collecting the excreta from individual houses and public toilets by buckets and vacuum tankers for use in agriculture and aquaculture. Most of the approximately 30 million tons of sludges that are reportedly collected in China's cities every year are used untreated. Concern

[1] Although water-borne excreta disposal through sewerage systems and central treatment works appears to be a feasible solution for most cities in industrialised countries, there is increasing concern regarding the long-term affordability and sustainability of the chosen options. Planners and applied researchers are increasingly embarking on the search for alternative concepts

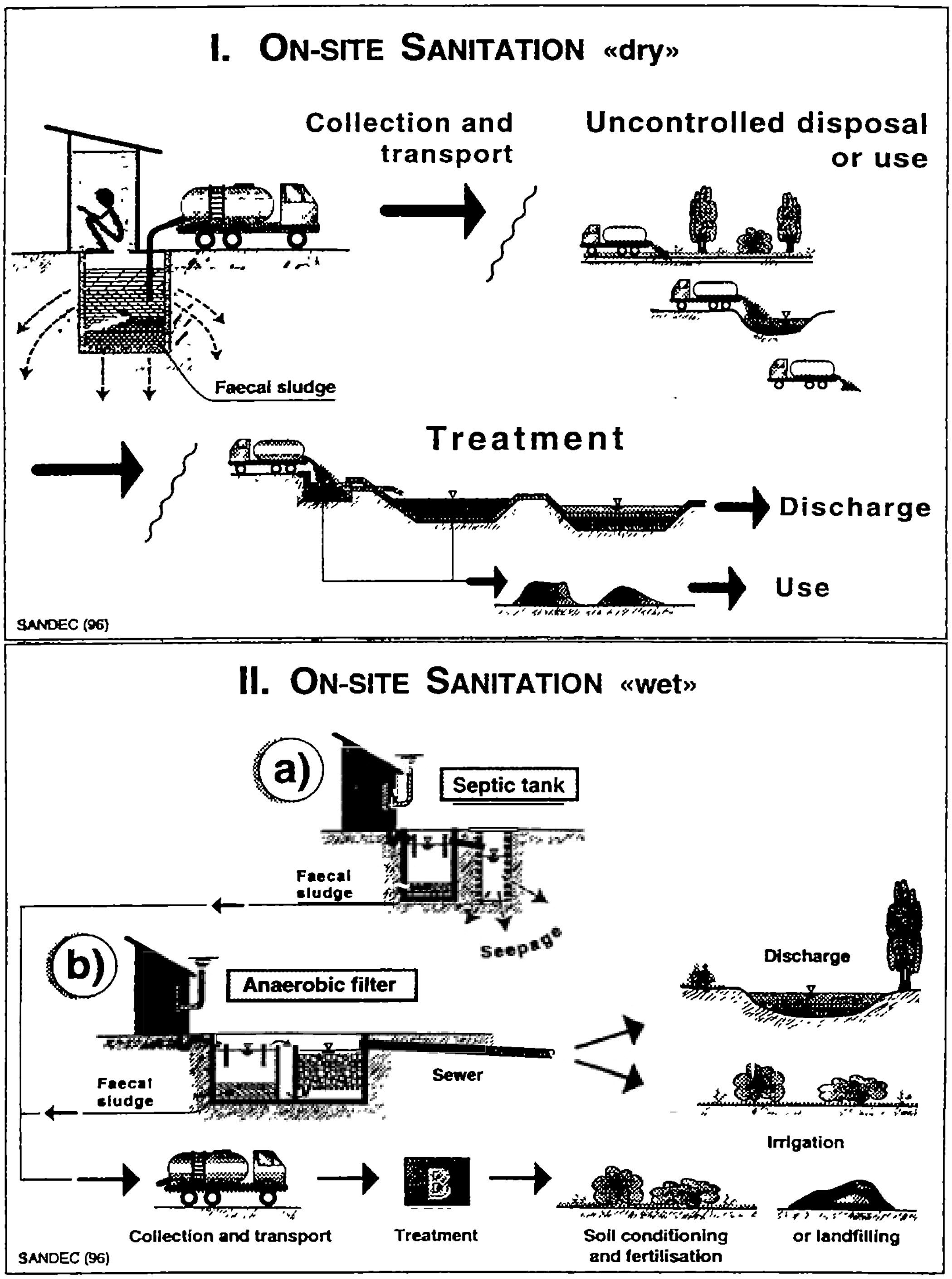


Figure 1 : Schematic illustration of non-sewered sanitation systems.

regarding the potential health impact has led Chinese authorities and research institutions to increasingly engage in research and development (R+D) for FS treatment (Ministry of Construction, P.R. China, 1993).

Table 1 lists FS disposal/treatment situations in a few selected countries and urban areas (Strauss and Heinss 1995).

The problem of FS disposal has also got a **quantitative dimension**: in most cities, the rate at which septic tanks and latrines are being emptied is far below the frequency required for a proper functioning of the installations and hence prevention of surface water pollution. Furthermore, emptying services lack capacity and many pits are not accessible by emptying vehicles. Authorities in Manila (pop. 8 mill.), e.g., estimate the number of septic tanks to amount to 1.5 million by the year 2000 serving about 65 % of the population (Veroy, Arellano and Sahagun 1994). Of the 1.5 mill. septic tanks, in the order of 190,000 should then be emptied each year. If the emptying services can be stepped up as planned, 3,000 m^3 of FS will be collected daily. In Bangkok (pop. 7 mill.), 65 % of the population are linked to aqua privies and septic tanks (Stoll 1995). Over 5,000 m^3 of FS are reportedly produced daily. Yet, only 10 % are collected.

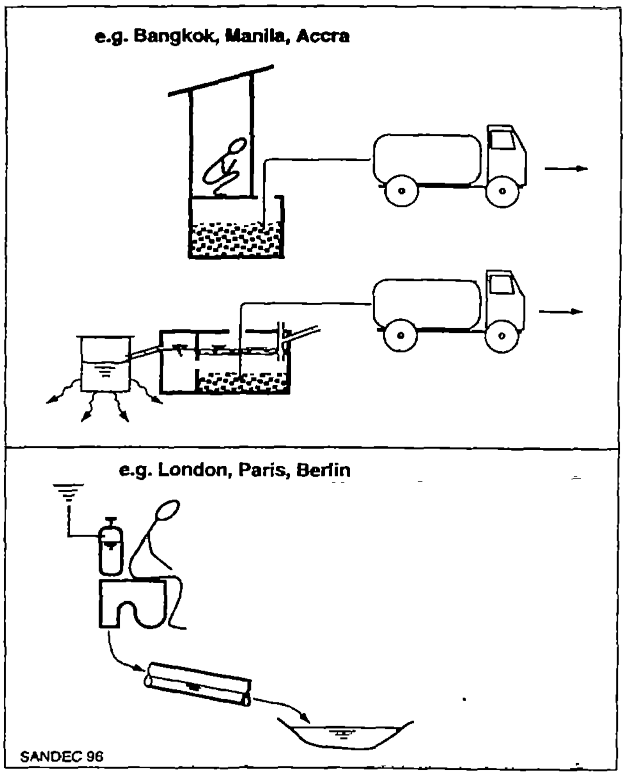


Figure 2: Non-sewered versus sewered urban excreta disposal.

These figures indicate that the authorities in charge of collection services are faced with a shear unresolvable task. Assuming the average vacuum tanker capacity to be 10 m3 (and this would be far too large for a vehicle to enter densely built-up areas !), the two cities would have to cater for 300 and 500 tanker loads, respectively, every day.

Most of the FS produced in cities of the developing and newly industrialising countries remains unaccounted for. Also, for various reasons, the great majority of the on-site sanitation systems such as septic tanks and aqua privies are malfunctioning. Only a small fraction of the FS produced and collected in the cities is subjected to treatment prior to discharge or use. As a consequence, the urban environment is continuously charged by high loads of excreta-related pathogens and organic pollutants leading to the contamination of ground and surface waters, soils, and crops grown in urban agriculture.

The fact that FS are usually disposed of untreated is mainly due to the lack of treatment options adapted to the socio-economic conditions of developing and newly industrialising countries. The treatment technology should be based on locally available and serviceable material and equipment that are simple to operate and maintain.

1.10.1.2 Why to Treat Faecal Sludges ?

The disposal of faecal sludges, whether controlled or uncontrolled, leads to environmental pollution, potential (and probably also true) spreading of excreta-related infections and to aesthetic degradation of urban areas. The environmental impact comprises the pollution of surface and shallow groundwater. The protection of surface waters is essential to prevent eutrophication and oxygen depletion in order to maintain fish life in rivers and estuaries. The protection of groundwater is important as people, mostly those from the poorer segment of the population, may depend on the shallow groundwater as a drinking water supply.

Contaminated surface waters may put at risk those urban and peri-urban dwellers who depend on these waters for their domestic and personal hygiene. While wash water must not comply with drinking water standards, contact with waters carrying heavy pathogen loads may potentially lead to the transmission of enteric infections. Water from open drains and small rivers within the urban or peri-urban perimeter are often used by horticulturists to grow cash crops for the urban market. The use of irrigation water loaded with untreated faecal sludges brings about substantial occupational and consumer risks.

Table 1: Examples of faecal sludge disposal, use and treatment practices.

City/Country	Disposal /use without treatment	Separate treatment	Combined treatment
Africa			
• Goborone and Lobatse (Botswana)	—	—	Co-treatment with wastewater in WSP
• Kumasi (Ghana)	Discharge into streams	—	—
• Accra (Ghana)	Sea disposal (for excess sludge)	Settling / thickening followed by ponds; composting of separated solids with sawdust or solid waste	—
• South Africa	—	—	Mostly co-treatment in act.sludge treatment plants
• Grahamstown (South Africa)	—	—	Co-composting with municipal refuse
• Maseru (Lesotho)	Trenching ground	Drying lagoons	—
• Cotonou (Benin)	Evaporation lagoons	—	—
• Dar es Salaam (Tanzania)	Sea disposal through wastewater outfalls	—	Co-treatment with wastewater in WSP
Asia			
• Manila (Philippines)	Mostly unaccounted for; discharged into drains + outfalls	—	Minor quantities: co-treatment with wastewater in WSP
• Jakarta (Indonesia)	Storm drains and canals; mostly unaccounted for	Extended aeration followed by ponds; drying beds for separated sludge	—
• China (unsewered parts of urban areas)	Agricultural or aquacultural use	—	—

Pathogens shed in human excreta die off at exponential rates upon leaving the human intestinal tract. They are, however, of variable persistence, decisive factor for the potential transmission of the respective diseases. Table 2 shows average pathogen die-off periods in faecal sludge and wastewater at ambient temperatures in tropical and temperate climate.

1.10.1.3 Faecal Sludges: Per-Capita Quantity and Characteristics

The daily per capita FS production or, rather, the daily volume of FS collected and discharged per person served, is essential for the planning and design of improved FS treatment and disposal systems. In contrast to the daily per capita sewage production, figures for FS as collected and discharged in a plant or elsewhere, depend on a multitude of factors and are thus difficult to estimate. Moreover, much of the generated and disposed of faecal sludge remains unaccounted for since in many cities only few sectors are regularly served by emptying and collection vehicles.

Table 2: Survival periods of excreta related pathogens in faecal sludge at ambient temperatres.

Organism	Average survival time at ambient temperature in wet faecal sludge and wastewater			
	In *temperate* climates (10-15EC) (days)		In *tropical* climates (20-30EC) (days)	
	Wet f. sludge	Wastewater	Wet f sludge	Wastewater
CViruses	< 100	> 50	< 20	< 50
CBacteria: -Samonella -Cholera -Fecal coliform	 < 100 < 30 <150	 < 150 < 30 < 120	 <30 < 5 < 50	 <30 < 5 <30
CProtozoa	< 30	> 50	< 15	< 15
CHelmiths: -Ascaris eggs -Tapeworm eggs	 2-3 year 12 months	 accum. in sludge accum in sludge	 10-12 months 6 months	 accum. in sludge accum. in sludge

The collected or collectable daily per capita FS quantities are dependant on the following factors:

- Latrine or septic tank emptying practice (frequency, ease and depth of emptying; water quantities used for dilution during emptying).
- Groundwater level: high levels during rainy seasons e.g. may limit the infiltration capacity of soak pits or drains and call for more frequent tank emptying.
- Capacity of seepage pits or drains (clogging leads to back-up problems).
- Origin of FS: Septic tanks; latrines; public toilet vaults.
- Accounting, fee collection and reporting practice.
- The usage pattern of aqua privies, cesspools and septic tanks (e.g. separate or non-separate disposal of greywater

It is not surprising that the per capita quantities, as reported in the literature, vary widely. Figures for collected septage (= faecal sludge retained in septic tanks) can be as low as 0.3 litres/cap day and as high as 13 l/cap day. The majority of reported values varies between 0.5 and 1 l/cap day.

Similar to the figures for collected per capita quantities, FS characteristics vary greatly, too, and depend mainly on the following factors:

- Origin/type of FS: septic tanks; pit latrines; public toilet vaults; this determines to a large extent the concentration of specific constituents and the "freshness" of the material; i.e., the degree of organic stability reached prior to collection
- Extent of storm or groundwater infiltration into latrine or septic tanks vaults.
- Emptying frequency.

Faecal sludges may be classified in two broad categories (Heinss and Strauss 1996): High-strength sludges from bucket privies or unsewered public toilets, and sludges of relatively weak strength, such as septage. Table 3 lists the main characteristics of the two types of FS.

Table 3: Important characteristics and classification of faecal sludges.

Item	High-strenght	Low-strenght	Sewage for comparison
Example	Public toilet or bucket latrine sludge	Septage	Tropical sewage
Characteri-sation	highly concentrated, mostly fresh FS; stored for days or weeks only	FS of low concentration; usually stored for several years	
COD	20, - 50,000 mg/l	< 10,000 mg/l	500 - 2,500 mg/l
COD.BOD	5:1 - 1:10	2:1 - 5:1	2:1
NH_4-N	2, - 5,000 mg/l	< 1,000 mg/l	30 - 70 mg/l
TS	$ 3.5 %	< 3%	< 1%
Helmith eggs	20, - 60,000 /l	# 4,000 /l	300 - 2,000/l mg/l

Truncating FS into two broad categories is important, particularly when treating sludges by solids-liquid separation such as sedimentation/thickening and sludge drying beds, or in ponds.

BOD, although routinely used in wastewater analysis and for the design of waste stabilisation ponds, is difficult to determine in a reliable manner for faecal sludges. BOD bottles should be continuously stirred or periodically shaken during the entire five days of testing, particularly when analysing FS which is rich in settleable solids such as public toilet or pit latrine sludge. Comparative BOD tests conducted at WRRI in Accra, Ghana (Stalder 1996), showed that the BOD analysed in stirred bottles was higher than the BOD determined in unstirred bottles by a factor of 1.4 on the average. Yet, rarely do laboratories in developing countries avail of shaking or multiple-place stirring equipment. Neither is this be affordable in most cases. Reported BOD data may therefore not be taken by their absolute values. It is advisable to routinely determine BOD via the COD analysis. Reported and measured COD/BOD ratios are listed in Table 3 above. More in-depth analyses should be performed to confirm the respective figures for the various types of FS.

Faecal sludges in developing countries are likely to contain high loads of helminth eggs (mostly nematodes such as *Ascaris*) as is shown in Table 2. Where helminthic diseases are endemic, eggs constitute the hygienic indicator of choice for untreated sludges as well as for sludges and compost produced in the treatment process. Moderately sophisticated analytical techniques for the quantitative determination of helminth eggs have been developed by Schwartzbrod et al. (1990).

1.10.2 The Treatment of Faecal Sludges

1.10.2.1 Theoretical Options

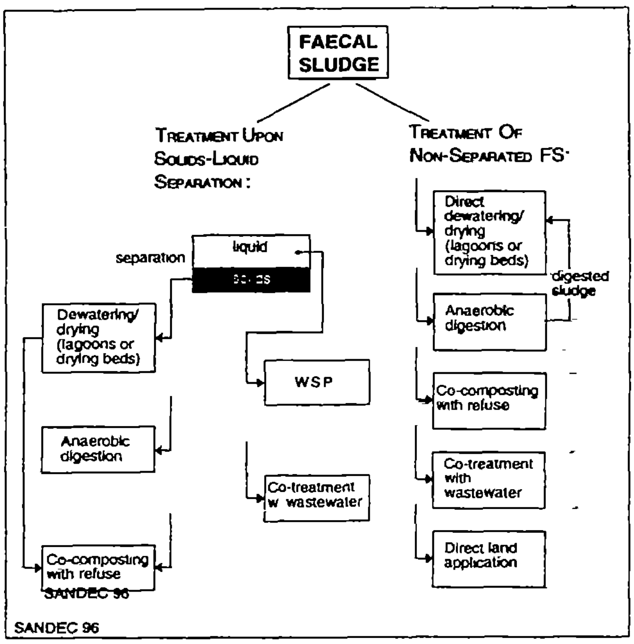


Figure 3: Theoretical options for treating sludges.

Fig. 3 shows a non-exhaustive listing of theoretical options for treating faecal sludges (Strauss and Heinss 1995). One basic distinction which can be made in classifying faecal sludge treatment options is between options with and options without solids-liquid separation. Another way of classifying FS treatment options is by distinguishing between separate treatment of faecal sludges and co-treatment. Co-treatment is meant to designate options by which septage or latrine sludges are treated jointly with municipal wastewater, wastewater treatment plant sludge, household/ municipal solid wastes or with organic residues such as sawdust or woodchips.

1.10.2.2 Priority Options

Methods for treating human wastes in developing as well as in newly industrialising should in most cases be relatively low-cost, i.e. low in capital and low in operating cost. Also, chosen systems must be compatible with the expertise available in the particular country at different professional levels. These criteria call for systems with a low or modest level of mechanisation and concomitant minimum artificial energy input. The disadvantage of low-cost treatment options is their large land requirement. This, in turn, creates a great challenge in fast growing urban agglomerations where land is getting increasingly scarce and hence relatively costly. It is usually reserved for either building or urban infrastructure development (e.g. roads) or for intensive agriculture. If FS treatment plants would be located too far away from city centres where land is less costly and more easily available, haulage distances would become excessive and cost considerations would lead to uncontrolled FS disposal closer to city centres. Therefore, the selection of appropriate options for the treatment of faecal sludges (and wastewater) must represent a sensible compromise with respect to these factors. A feasible strategy may consist in establishing decentralised, small to medium size treatment plants serving a selected number of urban districts or zones.

Below, treatment options are listed which may be considered particularly suitable technically as well as economically for developing and/or newly industrialising countries (Strauss and Heinss 1995; Strauss, Larmie and Heinss 1995).

A Solids/liquid separation by:
- A1 -Settling/thickening
- A2 -Dewatering and drying on unplanted or planted sludge dryin beds

B Stabilisation pond (lagoon) treatment (with or without prior solids-liquid separation)
C Co-composting of faecal sludges with household/municipal refuse
D Anaerobic digestion
E Extended aeration of septage followed by facultative and maturation ponds
F Co-treating FS and wastewater in waste stabilisation ponds (WSP)

Extended aeration of septage (Option E), although exhibiting a considerable level of sophistication, might indeed be suitable for metropolitan areas of e.g. newly industrialising countries where land is scarce and not available within useful haulage distances. Two FSTP using this option have been operated in Jakarta, Indonesia, for a number of years, already.

Below, options A - F are illustrated and briefly discussed.

A1 Solids-Liquid Separation - Settling /Thickening

Solids/liquid separation and thickening in separate treatment units might be a desirable treatment step in a scheme comprising FS stabilisation ponds. An alternative would be to use the first pond in a WSP system to achieve the desired solids-liquid separation. However, the removal of settled sludge and scum in "handable" portions from settling tanks at the time once a week or every few weeks may operationally be more advantageous than having to remove much larger volumes of settled sludge from primary ponds once every few years.

Clarifiers in WWTP in industrialised countries are normally equipped with automated, continuous sludge removal installations. Such capital and equipment intensive installations may, however, not be feasible in most developing countries. There, batch-operated FS settling/thickening tanks might be the option-of-choice. Settled and floating sludge solids may be removed by hand-driven scraping installations; gravity flow under hydrostatic pressure (bottom sludge only); or by front-end loaders via an access ramp.

The required storage volume for the separated solids is the decisive design variable for batch-operated FS settling/thickening tanks. This is in contrast to wastewater sedimentation tanks which are designed on the basis of the liquid and solids surface loading rates. The tank volume calculated to store the settleable FS solids has to be verified to guarantee a minimum liquid retention time (in the order of three hours) in the clear/settling zone. The sludge storage volume for the tanks used at the Achimota FSTP, Accra (rectangular tanks; batch cycles of several weeks; access ramp for accumulated sludge removal by front-end-loader) can be calculated on the basis of the attainable thickening concentration of the settled and floating sludge (#15 %), and on the desired length of the operating cycle (e.g. 2-4 weeks).

Fig. 4 shows a batch-operated settling/thickening tank of the kind used in Accra, Ghana, with a ramp for front-end loader removal of the separated solids (Heinss and Strauss 1996).

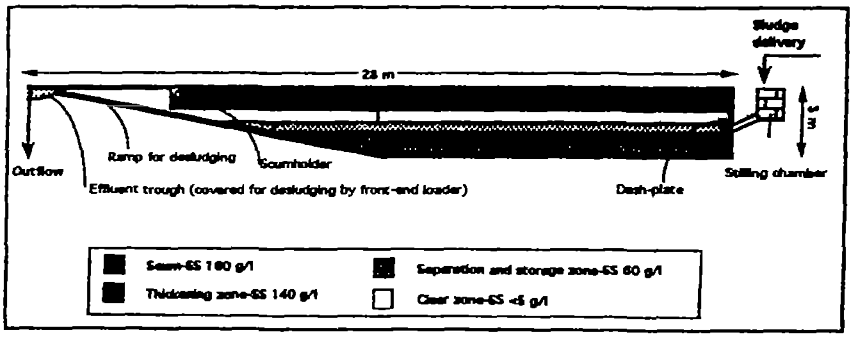


Figure 4: Batch operated sedimentation/thickening tank providing storage for approximately 50 tons of seperated solids (desludging by front end loader).

A2 *Solids-Liquid Separation - Unplanted or Planted Sludge Drying Beds*

Drying beds are or have been widely used throughout Europe and North America for dewatering sludges from wastewater treatment plants. Like lagoons, drying beds require much space. Therefore, as land became increasingly scarce and expensive and WWTP sludge quantities increased, this treatment option had to be replaced by less land-intensive dewatering processes such as chemical-aided centrifuging or filter pressing.

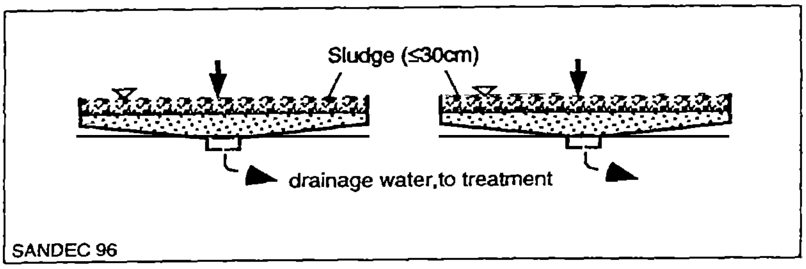


Figure 5: Sludge dewatering / drying bed.

Two processes are responsible for the dewatering and drying of sludges in unplanted sludge drying beds: gravity percolation and evaporation; whereas evapotranspiration is a supplementary process in planted drying beds.

First published experiments on faecal sludges treatment in unplanted sludge drying beds were conducted by a group of researchers at AIT, Bangkok, in the late sixties (Pescod 1971). A sludge depth of 20 cm was found to give maximum allowable solids loading rates. The drying periods required to achieve 25 % lasted from 5 to 15 days, depending on the solids (TS) loading rates (70 - 475 kg TS/m²yr) and on climatic conditions (rainfall vs. dry seasons).

Results obtained from the first monitoring phase of the pilot sludge drying beds in Accra/Ghana (Larmie 1995 and 1996) revealed that this treatment option is applicable to septage, public toilet sludge and primary pond sludge (TS = 1.6-7 %). Experiments were conducted during the dry season with sludge depths of # 20 cm. A 1:4 mixture of public toilet sludge and septage was dried to over 70 % TS in nine days at a solids loading rate of 130 kg TS/m²yr. Public toilet and primary pond sludges were dried to almost 40 % TS in 12 days at a solids loading rate of 200 kg TS//m²yr. A 95 % suspended solids (SS) elimination in the percolating liquid was achieved. Helminth egg elimination is a relevant factor if the dewatered or dried sludge is to be used in agriculture. Tests carried out to date tend to indicate that complete egg elimination is achieved only when the sludge will have dried to # 70 % TS. The corresponding drying period is dependant on the sludge loading rate (expressed e.g. as kg TS/m²yr) and climatic conditions.

Removal of the dewatered or dried sludge from unplanted sludge drying beds is labour intensive or requires mechanical equipment. Planted sludge drying beds could minimise the need of frequent dried sludge removal, as sludge withdrawal becomes necessary only after several years of operation. There exist a considerable number of reed beds treat sludge mainly from smaller STP in Europe and North America. Since the applicability of reed beds for faecal sludge treatment has not been tested except in a pilot scheme in France (Payrastre 1995), the process will be investigated upon on pilot scale in a joint field research project of AIT and EAWAG/SANDEC.

The monitoring results from planted and unplanted drying beds treating sludges from activated sludge treatment plants reveal that the percolating liquid is substantially nitrified. This renders the drying bed effluent particularly suitable for pond treatment as ammonia (NH_3) concentrations might be low enough to not inhibit algal growth (see Sect. B below regarding NH_3 toxicity in ponds).

Sedimentation/Thickening vs Drying Beds
Table 4 contains the per-capita surface area required for the two solids/liquid separation processes, described above, viz. sedimentation/thickening and drying beds (Heinss and Strauss 1996). FS treatment in a sedimentation/thickening tank requires a significantly (approx. ten times) smaller area than in a sludge drying bed. However, FS treatment in dewatering/drying beds yields a final sludge product of TS # 70 % whereas the achievable TS concentration in settling/thickening tanks amounts to # 14 % only. The thus obtained sludge requires further dewatering or co-composting. The COD, SS (suspended solids) and helminth egg concentrations in the effluent from drying beds are substantially lower than in the effluent from sedimentation/thickening tanks, and thus require less polishing. In choosing between settling/thickening and drying bed treatment, careful attention should thus be paid to factors such as the required land area, quality of the liquid effluents and of the sludges produced, and requirements for their further treatment.

Table 4: Comparing of settling/thickening and drying bed treatmet for solids/liquid seperation of faecal sludges.

	Attainable TS %	Assumed loading cycle	TS Loading kg TS/m^2yr	Area Required $m^2/cap.^{1)}$
Sedimentation Tank	≤ 14	8 weeks cycle (4 weeks loading + 4 weeks resting; 6 cycles per year) with two parallel settling tanks	1,000	0.007
Sludge Drying Bed (unplanted)	≤ 70	10-day cycle (loading-drying-removing; 36 cycles per year)	100 - 200	0.05

1) Assumed parameters. FS quantity = 1 litre/cap_day; TS of the untreated FS = 20 g/l

B: Stabilisation pond (lagoon) treatment (with or without prior solids-liquid separation)

Waste stabilisation ponds (WSP) represent a low-cost, potentially sustainable technology which finds increasing use world-wide for treating liquid and semi-liquid wastes. Substantial knowledge has been accumulated in recent decades as to the design and operation of WSP schemes treating wastewater (Mara and Pearson 1986 and 1992).

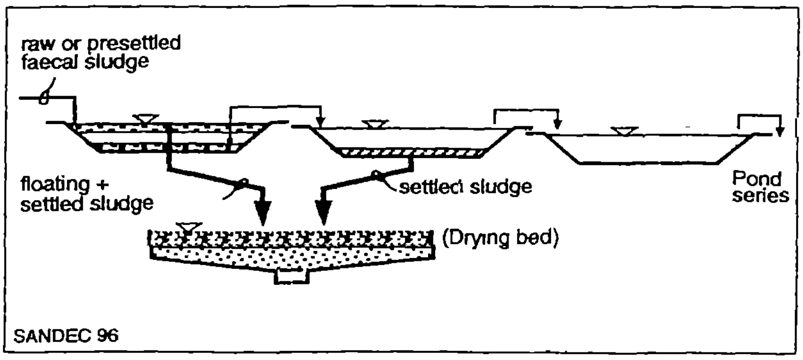


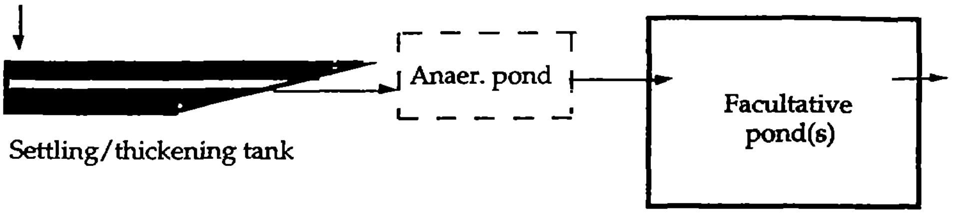
Figure 6: A waste stabilisation pond system for faecal sludge treatment.

Pond treatment has been adopted as the method-of-choice in Indonesia for treating septage (Ministry of Public Works, Gov. of Indonesia 1992). More than 10 such plants have been installed in the recent past. In some of the plants, Imhoff tanks have been installed as a pre-treatment for solids and partial organic removal. Two plants in Jakarta use extended aeration prior to ponds to oxidise substantial parts of the organic load prior to pond treatment. Lagoon treatment of septage (without the admixing of wastewater) is widely used in the United States, particularly so in the north-eastern states[2] (US EPA 1984). There, pond schemes usually consist of a primary pond for solids separation and partial degradation, followed by a secondary percolation/infiltration pond. The author is further aware of a few pond systems in Ghana (3 in operation, several being planned, all using settling/thickening as a pre-treatment step for solids removal) and one recently constructed for the city of Cotonou, Benin. Ponds are also used in Argentina.

Based on the knowledge acquired to date, we recommend that high and low strength sludges (see 1.4 above for the respective classification) be treated in separate pond systems. This would be beneficial as highly loaded, multi-stage **anaerobic ponds** are particularly suitable to achieve an efficient treatment of high-strength sludges. High loading rates lead to higher volumetric BOD removal rates and hence, to less overall pond surface or volume than in treating dilute faecal sludge.

High ammonia concentrations inhibit algal growth. Ammonium (NH_4) concentrations in the influent to facultative ponds should not exceed 400 mg/l. Corresponding ammonia (NH_3) levels will then not be inhibitory to algae. High-strength or mixtures of high and low-strength sludges containing high nitrogen loads are not amenable to **facultative pond** treatment. In contrast to this, septage is likely to be treatable in facultative ponds as its NH_4 and hence NH3 contents are relatively low.

2 25 % of the U.S. population are served by septic tanks rather than by sewerage schemes.



Sedimentation/ Thickening	**Anaerobic pond**	**Facultative pond(s)**
• Batch-operated • Attainable TS: 15% • Liquid retention ≥ 3 h in the clear / settling zone • Attainable elimination: BOD and COD: 50 % SS: 60-80 % Helminth eggs 50 %	• The need/benefit of anaerobic ponds for treating septage is still uncertain. It is likely to be advantageous if a BOD elimination of ≥ 40 % can be achieved. • $L_v \leq 350$ g/m^3·day, depending on temperature	• BOD elimination 80% • Retention time > 5 days • $L_a \leq 350$ kg/ha·day, depending on temperature
L_v = Volumetric organic loading rate L_a = Aerial organic loading rate		

Figure 7: Functional sketch and design guideline for pond treatment of septage.

Fig. 7 above schematically depicts and provides **design guidance** for **treating septage** in a facultative pond system in warm climates, preceded by a settling/thickening unit and an optional anaerobic pond (Heinss and Strauss 1996).

Field research is being conducted by the Ghana Water Resources Research Institute (WRRI) at a full-scale FSTP in Accra. The plant comprises five ponds in series preceded by settling/thickening. The data generated to date (Larmie 1996), indicate that BOD removal in the primary anaerobic pond following settling/thickening might be in the order of 50 %. The monitored volumetric and surface loading rates of this pond amounted to 100 g BOD/m^3 day and 1,300 kg BOD/ha day respectively.

C Thermophilic co-composting of faecal sludges with household/municipal refuse

Co-composting usually designates the combined composting of faecal or wastewater treatment sludges with household or municipal compostable refuse. It is both a traditional process as well as a fairly recent "discovery" being tried in a few places. In a wider sense, it may also comprise the joint composting of sludges with other organic material which allows to achieve optimum C/N ratios in the mixture to be composted. Suitable materials might be sawdust, wood chips, bark, slaughterhouse or food industry waste. The role of the material added to the sludge is to create a C/N ratio required for optimum composting. The ratio should be between 20-30, whereas the C/N ratios in faecal sludges range from about 2-3 in fresh excreta to around 6-15 in septage. Optimum moisture contents of the raw material should amount to 40-60 %.

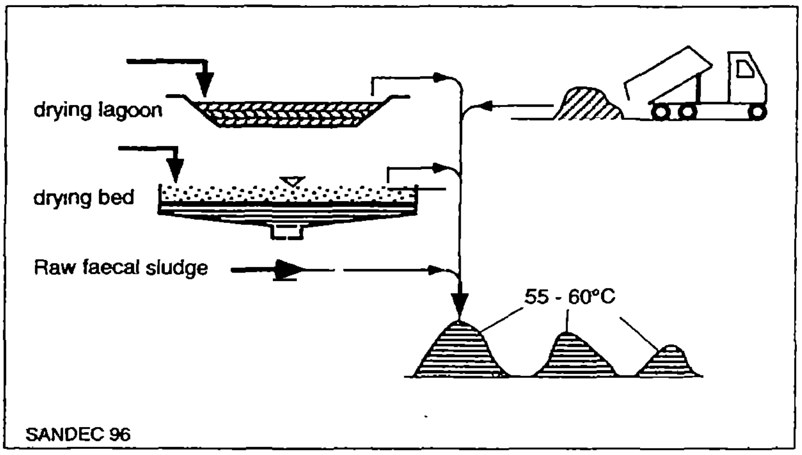


Figure 8: Co-composting for faecal sludge and refuse.

Co-composting is being practised for varying periods of time, in some cases for decades, already, e.g. in Vietnam, China, India, Malaya, Singapore and Nigeria. Nightsoil is co-composted with either refuse and/or other organic/bulking material. Mixing ratios are reported to be in the order of 1:5 - 1:10 (sludge : added material) on a wet weight basis if non-dewatered sludge is used. With dewatered sludge, the ratio can be increased to as much as 1:1.5 (Scott 1952; Shuval et al. 1981; Obeng and Wright 1987).
An example of a recent operation is the installation at Rini near Grahamstown, South Africa (La Trobe and Ross 1992). There, the refuse and bucket latrine sludge from a community of 100,000 are co-composted in a simply mechanised plant using forced-aerated, static windrows. The nightsoil is pre-settled and then hosed on to the windrows as the garbage is being heaped up. On a volume basis, the mixing ratio is approx. 1:10. The process is controlled by the temperatures developing within the piles. 55 /C are reached and the windrows are left to react for 3 weeks. After composting, the mixture is being sieved and the rejects landfilled. The compost is used by the Grahamstown garden department after additional maturing. The Council for Scientific and Industrial Research (CSIR) of South Africa, and the Wuhan Construction Institute in China are presently carrying out pilot investigations on the co-composting of latrine sludges with municipal solid waste.

D Anaerobic digestion

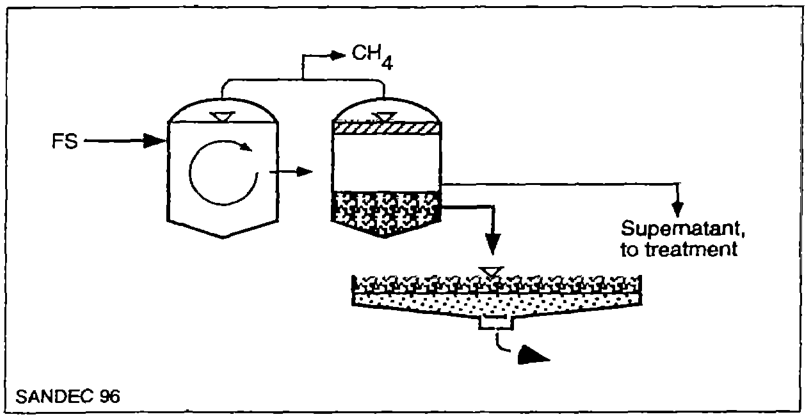


Figure 9: Anaerobic digestion for faecal sludges (seperate treatment).

Faecal sludges are amenable to anaerobic digestion either in separate treatment plants or by adding the FS to the anaerobic digestion units of wastewater treatment plants. Anaerobic digestion is a process widely used e.g. in Japan and in South Korea for the treatment of septage and other faecal sludges in centralised, so-called nightsoil treatment plants. In South Korea, the sludges are mechanically dewatered after digestion and either landfilled or co-composted with organic waste from farms in small rural-based composting plants. The supernatant from the anaerobic digestion is diluted with fresh water and treated by activated sludge. Digesters may represent an economical solution for FS treatment in warm climates, as temperatures are continuously high allowing anaerobic digestion to proceed in unheated units. In India, FS from public pour-flush toilets developed and operated by Sulabh International, a Delhi-based NGO, is subjected to anaerobic digestion in unheated biogas plants. Such digesters have been installed and are operational in 60 out of 3,000+ public toilets run by Sulabh. The majority of the digesters are fixed dome units with sizes ranging from 30-60 m3 serving public toilets for 500-5,000 users per day. The gas produced is being used for street lighting, for lighting and cooking in the quarters of the toilet caretakers, and for electricity generation (in larger toilet complexes, only).

Results of investigations carried out on laboratory scale at AIT in Bangkok have been published by Pescod in 1971. NEERI and Sulabh International (India) have conducted investigations on and monitored **decentralised, full-scale biogas plants** treating faecal sludges ("nightsoil") from public toilets in the sixties, seventies and eighties (Satanarayan et al. 1987; Pathak and Jha 1993).

These authors provide the following design and operational data obtained at temperatures averaging 28 /C:

■ Hydraulic retention time:	20-30 days
■ Volume of excreta plus flush water per use:	3 litres
■ Loading rate:	1.5 - 2 kg VS/m3_day
■ Solids content of feed slurry:	3 - 6 %
■ Gas production:	0.3-0.4 m3/kg VS
■ Biogas production per user/day:	25 - 30 litres

Septage (the contents from septic tanks) is hardly amenable to anaerobic digestion at economic cost due to its low solids content and its organic stability which is normally higher than that of public toilet sludges.

E Extended aeration of septage followed by facultative and maturation ponds

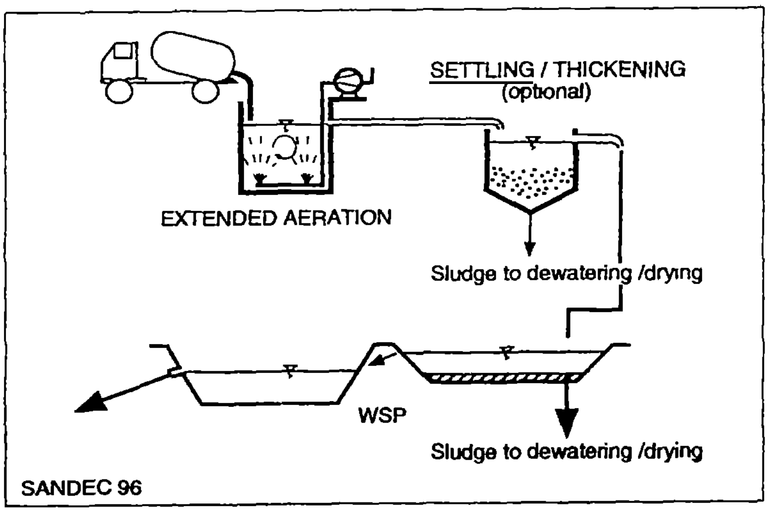


Figure 10: Extended aeration followed by pond treatment.

Extended aeration of septage is an option requiring substantial capital investment for mechanical equipment and consuming relatively large amounts of energy for operation. Yet, these disadvantages may be offset by reduced land use, thus allowing a plant to be installed closer to city centres than more land-intensive systems. The objective of aerating the septage in an initial treatment step is to achieve substantial BOD and COD removals. This reduces the organic load and thereby the size of ponds required for polishing treatment. Further to this, aeration will lead to enhanced solids-liquid separation. The sludge formed upon separation is more easily dewaterable than non-aerated septage and thus requires reduced drying areas. Assuming an aeration period of four days, it is estimated that 30 - 50 % of land savings may be achieved as against treating the FS in a conventional WSP system. Yet, field investigations on extended aeration plants would have to be conducted to substantiate this estimate.

F Co-treating FS and wastewater in waste stabilisation ponds (WSP)

Where WSP exist to treat municipal wastewater, the pond systems are often used to co-treat faecal sludges (see also Table 1). This may constitute a sensible options where FS organic and solids loads are small compared to the wastewater loads, where the additional loading brought in by the FS deliveries is adequately considered in the plant design and where adequate operational and maintenance measures are taken to maintain good pond performance. In many situations, however, these conditions are not being satisfied and WSP just represent a convenient place to dump the faecal sludges.

The more concentrated FS such as public toilet sludges exhibit high ammonium concentrations which cause the suppression of algal growth in facultative ponds. Co-mixing wastewater to presettled public toilet sludges may thus render the FS liquid amenable to facultative pond treatment.

The critical variables to be considered when co-treating wastewater and faecal sludges in waste stabilisation ponds are the organic loading rate, the solids load and the ammonium/ammonia nitrogen concentrations (Heinss and Strauss 1996). Their relevance is outlined below.

- **Organic loading rate:** anaerobic and facultative ponds are sensitive to excessive organic (BOD) loading. The most serious symptomatic effect in overloaded anaerobic ponds is odour. In facultative ponds, overloading will impair the development of aerobic conditions and algal growth. The permissible additional faecal sludge load is dependent on the organic load already exerted by the wastewater, and on the loading rates for which the ponds were originally designed

- **Solids load:** ponds may fill up at undesirably fast rates as a result of high solids contents in the faecal sludges. Separating the FS solids in solids/liquid treatment (e.g. settling/thickening or dewatering beds), and treating the liquid in wastewater stabilisation ponds is thus the recommended option which is likely to lead to a reliable and long lasting WSP operation. A 60-80 % removal of suspended solids can be achieved in well-designed and operated settling/thickening tanks. In dewatering/drying beds, a _ 90 % removal of suspended solids and a 100 % removal of helminth eggs from the FS liquid can be safely attained.

- **Ammonia nitrogen:** the permissible ammonia (NH_3) concentration in the facultative pond is a further factor influencing the permissible FS load in a WSP system. Excessive ammonia levels may cause a suppression of algal growth. This, in turn, reduces the supply of oxygen required by the aerobic bacteria for the decomposition of organic matter and by nitrifiers for the oxidation of NH_4. Under the conditions prevailing in facultative ponds in tropical climates, the permissible NH_4 concentration in the influent of the combined waste has been established at 400 mg/l, or 500 mg/l if the waste is pre-treated in an anaerobic pond. The FS : wastewater load ratio may be calculated on the basis of these critical concentrations.

1.10.3 Effluent and Plant Sludge Quality Guidelines

What effluent and plant sludge quality should one be heading for when planning and designing for faecal sludge treatment ?

In many of the less industrialised countries, there do not exist any effluent and natural water quality standards. In others, effluent discharge standards may exist for wastewater but not for faecal sludges. Examples for faecal sludge treatment standards are known from China and Ghana: In China, faecal sludges should be treated such that $ 95 % of the helminth eggs will be removed or inactivated (National Nightsoil Treatment Standards, P.R. China 1987). In Ghana, the Environmental Protection Commission has stipulated 90 % BOD and faecal coliform removal for the effluent to be discharged from the New Teshie FSTP in Accra (Annoh 1995). The plant was commissioned in 1995. The Indonesian government has issued design guidelines for septage treatment in 1992 (Ministry of Public Works, Indonesia 1992). However, effluent and plant sludge quality standards or guidelines are not stipulated in the respective document.

Many of the countries which have in fact adopted effluent discharge standards are often neither controlling nor enforcing them. Not unusually, sewage treatment plant effluent guidelines or standards are set at 20-30 mg BOD and suspended solids per litre, i.e. at levels commonly stipulated in many industrialised countries.

The following should be taken into consideration when deliberating about FSTP effluent and plant sludge quality guidelines:

- **Highly concentrated waste**: Faecal sludges are 10-100 times more concentrated than municipal wastewater. Their treatment in FSTP to achieve such effluent quality levels as are stipulated for WWTP effluents is hardly possible when using modest-cost treatment options. But neither might such stringent standards be feasible and required

- **Economically beyond reach**: To achieve unduly strict quality levels may in most cases not be possible for economic reasons. Land requirements would be excessive if low-cost treatment would be applied. Alternatively, capital and operating cost might be unaffordable if more sophisticated options would be selected.

- **Widely differing characteristics**: There exists a large variation in raw sludge quality, particularly so between relatively weak faecal sludges such as septage, and fresh, more concentrated sludges such as the contents from unsewered, non or low-flush public toilets. Achieving set quality standards may thus be variably difficult.

- **"Some already means a lot"**: To date, faecal sludges are in most places dumped uncontrolled and untreated into the aquatic and terrestrial environment. Treating the sludges prior to discharge or use will lead to substantial health and environmental improvements even if strict quality standards may not be met.

- **Discharge vs. reuse**: When stipulating effluent and plant sludge quality levels, a distinction should be made for the discharge into the aquatic or terrestrial environment and for the reuse in agriculture or aquaculture, respectively.

  For the discharge into the environment, variables such as COD or BOD and NH_4 are of prime importance. When discharging into aquatic environments such as seasonal or perennial rivers, estuaries or the sea, the degree of dilution in the receiving water may be taken into consideration. However, from an ecological viewpoint, limits should be stipulated in terms of discharged pollutant loads (expressed, e.g. as tons of COD/year) rather than in terms of pollutant concentrations.

  If the treated FS is to be reused, hygienic characteristics comprising helminth eggs as parasite indicators and faecal coliforms as bacterial indicators are the important variables. In addition, nitrogen constitutes an important criterion: in contrast to phosphorus, nitrogenous compounds are not retained/stored in the soil matrix. Therefore, groundwater will become contaminated by nitrogenous compounds if FS is used in a way which exceeds the plants" nitrogen requirements. These amount to 100- 200 kg N/ha_year, depending on the kind of crop.

- **Institutional capacity and political will**: When stipulating guidelines, consideration must also be given to the institutional capacities in controlling and enforcing them. Typically, in less industrialised countries, trained personnel and laboratory facilities for carrying out routine monitoring are lacking. Moreover, political will and legal tools may be inadequate to enforce standards. The violation of effluent standards may therefore go undetected. Monitoring requirements can be minimised if use is made of treatment options which if properly designed, constructed and operated below or at design loads are known to satisfy given effluent standards. They may not require frequent monitoring. WSP are an example of such an option.

In Table 5, effluent and plant sludge quality guidelines are listed. The suggested values are based on expected FSTP performance and on environmental criteria.

The suggested guideline figures are tentative and should be carefully scrutinised in the light of specific, local situations. Economic aspects and the specific characteristics of FS as compared to wastewater have been taken into consideration. The guideline figures may appear lenient compared to commonly used wastewater effluent guidelines. Yet, care should be taken when trying to enact more stringent quality guidelines. It would provoke large additional investments and call for more sophisticated technologies which, in turn, would render plant maintenance and operation more difficult and costly.

Table 5: Suggested effluent and plant sludge quality guidlelines for the treatment of faecal sludges (Heinss & Strauss 1996).

	COD (mg/l)	BOD (mg/l)	NH_4-N (mg/l)	Helm. eggs	Faecal coliforms no./100ml
A: Liquid effluent					
Treatment for discharge into receiving water:					
Seasonal stream or estuary	≤300-600	≤100-200	10-30	≤ 2 - 5 / litre	$\leq 10^4$
Penrennaial river or the sea	≤600-1,200	≤200-500	20-50	≤ 10 / litre	$\leq 10^5$
Treatment for reuse:					
Resticted irrigation	n c	n.c.	*	≤ 1 / litre	$\leq 10^5$
Vegetable irrigation	n.c.	n.c.	*	≤ 1 / litre	$\leq 10^3$
B: Treated plant sludge					
Use in agriculture	n.c	n.c.	n.c.	≤ 3 - 8 / g TS	Will be at safe level if egg standard is met

n.c. : not critical   * irrigation rates and hance effluent quality to be chosen such that the crop nitrogen requirements (100. .200 kg/ja year) are not surpassed.

1.10.4 Constraints to the Implementation of Low-Cost FS and Wastewater Treatment Systems

The following listing of suggested constraints is based on the author's own experience by eye, nose and ear, and on subjective thoughts and inferences.

- ***Faecal sludges on the poors' land***: Faecal sludges collected in urban areas are often disposed of untreated near or in areas inhabited by squatter settlers. The land they seize (illegally in most cases) such as in flood plains or on eroded slopes is often heavily degraded and serves as convenient dumping area. The poor make up substantial and growing proportions, in many cities constituting over 50 % of the urban population. The dumping of untreated wastes thus threatens the health of millions and leads to a continuous flux of viable pathogens into and through the urban population as a whole. Yet, authorities have little concern for those dwellers as their land occupancy status tends to render them non-recognised citizens.

- ***Sanitation work carries little prestige***: Sanitation is the least prestigious working field among professionals and public officials - in contrast to such fields as water supply, roads and airport construction, or electricity supply. This is may be reflected in low levels of budgetary provisions for sanitation works both for investments as well as for operation & maintenance, lack of qualified staff in the respective administrative institutions and low priority for upgrading works.

- ***Low-cost options vs. land use***: Low or modest-cost waste treatment systems are land intensive. Yet, land often represents a scarce and costly commodity in large urban agglomerations. The need for land to treat faecal sludges may thus be in a losing position in competing with the interests of such uses like roads, building development or intensive (vegetable) agriculture. Also, FSTP operations are associated with regular heavy vehicle traffic and occasional, though wind-dependant, odours, causing objections from nearby residents.

- ***Lack of knowledge on appropriate FS treatment options***: The development of appropriate FS treatment options is greatly lagging behind the development of wastewater treatment technology. In addition, many professionals in public administration who are responsible for urban infrastructure planning and implementation on a decision maker's or engineer's level may have been trained overseas. Hence they might be more familiar with what represents a suitable choice of options in industrialised countries (for wastewater treatment mainly) than what might constitute a feasible solution in the developing country context.

- ***Sanitary engineers' bias:*** Urban infrastructure planning, design and implementation for cities in developing countries is often being (co-) financed by external support agencies. Therefore, foreign engineering consulting firms become part of the support package in most cases. Yet, many of them are not familiar with or not genuinely interested in modest-cost waste management, including treatment. Their main objective is to maximise profits. Hence, they tend to propose capital-intensive options and are herein often supported by the financing agency.

- ***Faecal sludge management - many unresolved issues***: There are other, unresolved issues around FS management than just treatment:

  - The non-accessibility of toilet pits in congested low-income areas
  - Inadequate logistics for pit emptying
  - The unsustainability of long-distance haulage.

Efforts are being undertaken to manufacture pit emptying vehicles which can get into narrow streets and lanes, and thus manage to periodically empty toilets in low-income areas. Improving collection logistics requires suitable institutional adaptations, possibly linked to privatisation of collection services.

The haulage of relatively small volumes (5-10 m3 per truck) of FS through congested traffic over long distances in large urban agglomerations is not sustainable neither economically nor ecologically. (air pollution through vehicle exhaust). While FS haulage might be feasible for small to medium-size towns it may not be a feasible and long-term solution for large cities. Yet, developing countries and the majority of city dwellers cannot afford to install city-wide sewerage systems and pay for their use. Therefore, new concepts of FS collection and transport have to be developed. Efforts should thereby be made to minimise haulage volumes and mileage. The planning for and installation of FS treatment on a small to medium scale in decentralised treatment plants might contribute to alleviating the haulage problem. Such decentralised treatment may e.g. consist in the dewatering of the faecal sludges with a subsequent treatment and discharge (or reuse) of the separated liquid. Assuming the dewatering process (e.g. by sludge drying bed treatment) yielding a reduction in water content from 98 % to 75 %, the volume of dewatered sludge to be hauled away would be 12 times smaller than the raw FS volume ! The advantage of FS treatment in contrast to wastewater treatment is that the sites can be selected irrespective of the topography situation. Another concept proposed recently by planning consultants for a sanitation upgrading program in an Asian mega city consists in providing trunk sewers for faecal sludges into which vacuum tankers would discharge their loads. FS would then be flushed to the downstream end of the sewer where it could be treated. To render this "haulage" option economically viable topographic conditions would have to be such that pumping requirements would be minimal.

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1.11 Problems/Constraints Related to Wider Dissemination of More Sustainable Waste Water Treatment Technologies in Tanzania, *S. Mgana.*

University college of Lands and Architectural Studies (UCLAS),
Department of Environmental Engineering,
P.O.Box 35176, Dar es Salaam, Tanzania.
E-mail: mgana@udsm.ac.tz

1.11.1 Introduction

Tanzania lies just south of the equator between the lakes: Victoria, Tanganyika and Nyasa, on one hand and the Indian Ocean on the other (refer Map-A). Its area is 945,200 square kilometres and the population in 1994 was estimated at 28.8 million people. It has a coastline of 900 km long. With the exception of the narrow coastal belt most of the land lie above 200m altitude and much of the country is higher than 1,000m above sea level.

1.11.2 Development of Water and Sanitation Sector in Tanzania

Development of water supply in Tanzania started in the 1930s under the supervision of the Public Works Department until 1945 when the Water Development and Irrigation Department was established. During this time, priority was directed to urban settlements, trading centres, missions and large estates. Noticeable development in the rural areas started taking place in the fifties.

Under the then prevailing arrangements, local authorities were required to contribute 25% of the cost of rural water supply investments before the Central Government released the remaining 75%. This trend, not only delayed the speed for rural water supply construction, but resulted in disparities between the poor and the richer district councils. Operation and maintenance costs were met by the respective district councils out of revenues from the sale of water and other sources.

With the coming of the independence in 1960, the government re-directed attention to the provision of social infrastructure services (water supply, health and education) to the rural areas. In 1965, the Government took the responsibility of financing rural water supply construction including operation and maintenance.

In an attempt to accelerate the pace of rural water supply delivery, the Government in 1970, declared a 20-year (1971-1991) Rural Water Supply Programme. The programme aimed at achieving 100% coverage to within a service level of 400 metres of each household. The Programme attracted a number of external support agencies. The programme started with the preparation of regional water master plans and by 1982 a total of 16 Regional Water Master Plans had been prepared. Most of these Master Plans are yet to be implemented. The Master Plans serve as important reference material as they have been found to contain a lot of useful informantion on water resources. During

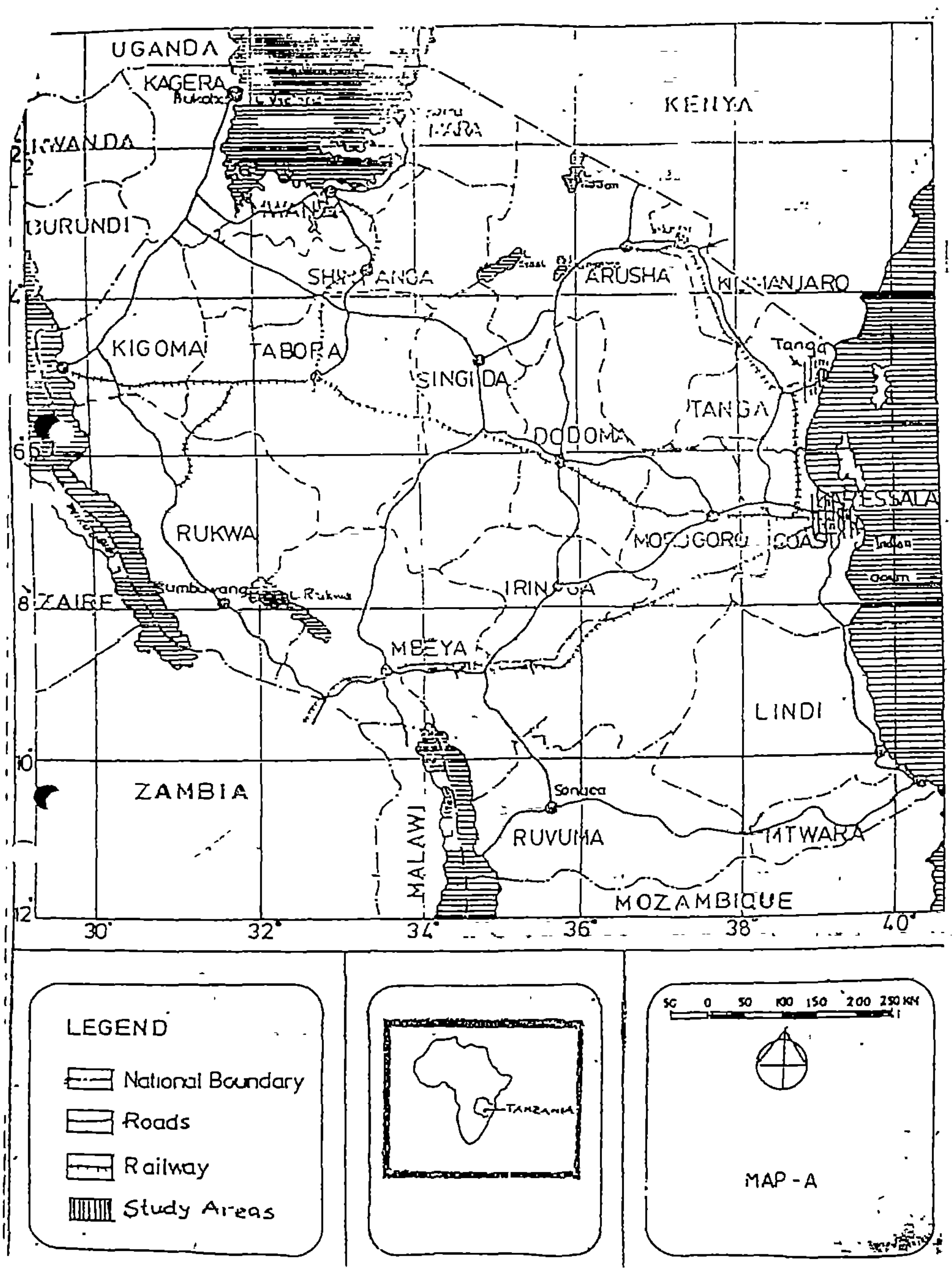

Figure 1: Map A, Tanzania.

implementation, donors adopted a regionalised approach using own standards and technologies, and community participatory approaches. This was characterised by marked regional disparities in terms of coverage and community participatory approaches.In 1986, when reviewing the Rural Water Supply Programme, it became evident that the targets set for 1991 cannot be met. Less than 42% of the rural population and 65% of the urban population had access to safe and potable water supply while sanitation situation in most urban centres was deplorable. All sewerage systems were partially or completely inoperative thus posing a serious health hazard. In the light of this, the Government revised the target to the year 2002. "Water for All by 2002", sanitation facilities for 95% of all households by the year 1997 and Health for all (primary health care) by the year 2000.

Although in theory sanitation has been incorporated in the planning processes for many years, its planning has been done on an ad-hoc basis. Consequently implementation of sanitation has always lagged behing water supply. The imbalance between water supply and sanitation has been attributed to several factors, inter alia, involvement of different institutions, low priority accorded to sanitation by the users themselves as well as decision makers at all levels.

Funding level for sewerage and sanitation has remained very low. Funds allocated annually for sewerage and sanitation since 1979 to-date average out to 0.45% of the total government development budget. Looked at from the actual requirement, the annual allocation as compared to the annual requirements according to the five year development plan has been on the average of 30%. This limited to a greater extent any meaningful intervention in trying to solve the current problems.

A survey conducted in the early 1980s to determine the level of sanitation in nine urban

Table 1: Current sanitation technologies in use in Tanzania and their suitabilities.

Sanitation systems	Rural application	Urban application	Construction cost	Operation cost	Easy of construction	Water requirement	Hygiene
Pit latrines (Traditional pit latrines)	Suitable in all areas	Suitable in high density suburbs	Low	Low except in urban due to collapse	Very easy except in wet or rocky ground	Little for sanitation	Seldom meet minimum health standdards/ moderate
VIP latrines	Suitable	Suitable except for water logged areas	Low in urban but high for income bracket	Low except for desludging	Easy	Little for sanitation	Very good
Septic tanks	Suitable	Suitable for low denity suburbs	Very high	Low except for emptying	Requires skilled builder	Water piped to privy	Excellent
Foul sewer	Not suitable	Suitable where can be afforded	Very high	Medium	Requres experienced engineer	Water piped to privy	Excellent
Storm water (a) channel drainage (b) piped	N.A. N.A.	Suitable Suitable					
Solid waste	Pit and incineration	Pit and inceneration	High in urban dump	High urban land fill dump	Require experienced engineer	None	Fair with environmental hazards
Sullage	Pit	Suitable sewers of drainage	Moderate	Low	Require skilled builder	Piped water is rquired in urban areas	Fair due to envionmental effects

councils revealed that 80% of the urban population depend on pit latrines as their excreta disposal facility while 10% use septic tanks, 5% connected to sewerage systems and 5% have no sanitation facility of any kind. Ninety percent of the rural population use pit latrines that, over 80% of the pit latrines are substandard.

The most recent estimates indicate that the population in the urban areas having access to safe water is 75% and in the rural areas is 46.4%.

On 16th November, 1991 the Government endorsed the water policy. The highlights of the policy include beneficiary participation, community-based management, rehabilitation, integration of water supply and sanitation, roles of the various actors in the sector (e.g. external support agencies, private sector and non-governmental organisations) and institutional aspects. This is a swift shift from the original position of state control. The government is now advocating private-public partinership on the delivery of social services.

1.11.3 Problems and constraints

A: General problems and constraints are:

- Government/State monopoly of the water and sanitation sector
- Lack of awareness/access to information
- Infeffective government policy
- Overall poor state of economy of the people and government
- Lack of local capabilities to promote these systems

B: Specific Problems / Constraints on:

- Government/State monopoly of the water and sanitation sector

Table 2: Professsional staff strength in 1995 in the Ministry of Water (and sanitation) and the required in 2002.

	1995					**2002**
Occupational category	WRI	H/Q	Region	District	Total	
1. Civil Engineer	5	35	97	14	146	200
2. Mechanical Engineer		7	19		27	176
3. Electrical Engineer		3	9		13	119
4. Environmental Engineer	1	17	8		25	32
5. Hydrologist	1	11	20		32	50
6. Hydrogeologist	6	5	35		40	100
7. Drilling Engineer		1			1	10
8. Research Officers	1	6	3		9	60

The demonstration pilot research projects will have major impact to the government decision makers if they involve inherent resource recovery and at the same time they are effective and low cost technologies.

■ Ineffective government policy

Government's comparative low priority to preventative health services (which includes waste water treatment systems) compared to curative health care. Between 1989 - 93, about 89% of the government budget on health sector (which includes preventative and curative health care) was spent on curative services, 7% on training and administration and only 4% on preventative systems.

Ineffective equitable charging systems for the waste water treatment systems.

Non participation of private business enterprises in the waste water treatment systems.

Lack of a functional and sustainable institutional set-up (administratively) for the waste water treatment systems.

Lack of effective pollution control advisory/regulatory agency/body which could give incentive to polluters to treat waste water to required standards.

■ Overall poor state of economy of the people and government

Low per capita income of the people
This means that sustainability of the waste water treatment systems could be achieved if based on the low income of the beneficiaries which in turn will influence the technology selection through a private sector approach.

However expansion of water and sanitation as a social service and the scope for sustaining it depend on continued aid, better performance in public administration and improvement in mobilizing and utilizing public resources. While private sector participation should be encouraged , this is only a partial solution given the high level of poverty. About half of the population is estimated to be living at very low of welfare.

Unstable accessibility to water
Urban population that has access to water has fallen from 90% in 1969 to 55% in 1993. In 1976 it was 76%.The rural population that had access to safe water in 1961 was 12% whereas in 1969 the figure fell to 7%. However in 1976 the percentage of rural population that had access to water rose to 25% . There was a decline in 1993 to 21%.
These statistics mean that over the years the water to waste varied in quantity and maybe in disposal methods. Based on this scenario waste water treatment technologies are most likely required to be highly flexible in design and operation in terms of scaling up or down with little effect on performance.

■ Lack of local capabilities to promote sustainable waste water treatment technologies

Present curriculum in engineering schools/colleges lack adequate coverage in waste water treatment technologies. This reality has led to inadequate capacity building at all levels of the waste water sector in terms of technical know how and population of technicians and specialists.

Untill recently the sanitation sector in the context of preventative health was not a priority to the Government as reflected in the allocation of government funds to the sector.

Funds allocated annually for sewerage and sanitation since 1979 to-date average out to 0.45% of the total government development budget. Looked at from the actual requirement, the annual allocation as compared to the annual requirements according to the five year development plan has been on the average of 30% This limited to a greater extent any meaningful intervention in trying to solve the current problems. This phenomenon had brought for a long time, lack of interest in the waste water treatment technologies by the engineering schools and students.

Inadequate research and curriculum development funding by the governments and donors to engineering schools/colleges to explore and localize waste water treatment technologies available in the north.

The construction industry and consulting profession in the water supply and sanitation sector in Tanzania is generally characterized by foreign private firms as well as few local firms, mostly in the public sector, that get their work without competition and dominate the market and technology.

On the other part, domestic private firms involvement in the water and sanitation delivery is confronted with problems that include: inadequate skilled personnel, managerial inefficiencies, poor marketing, poor access to capital, high interest rates and continuous devaluation of the local currency, lack of (or poor access to) credit facilities and poor transparency in award of contracts.

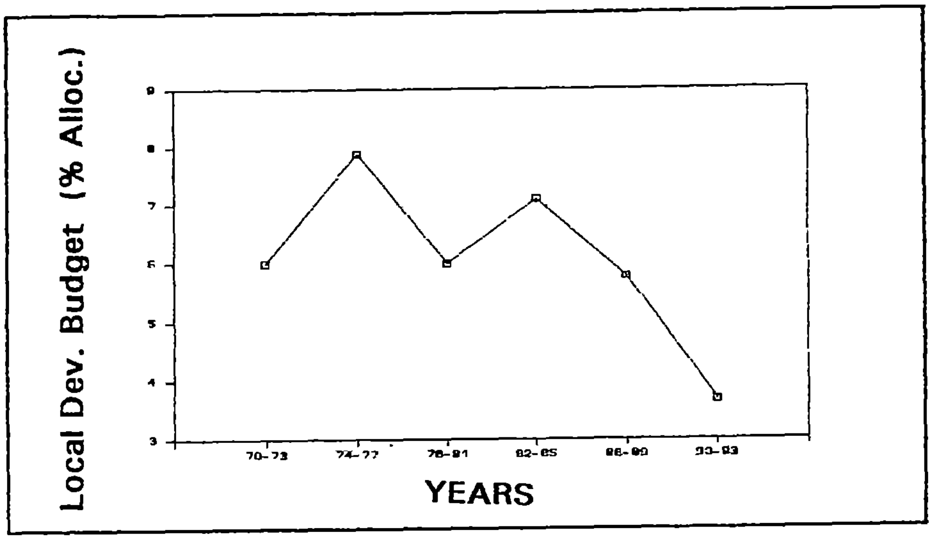

Figure 1: Tanzanian water sector local funding..

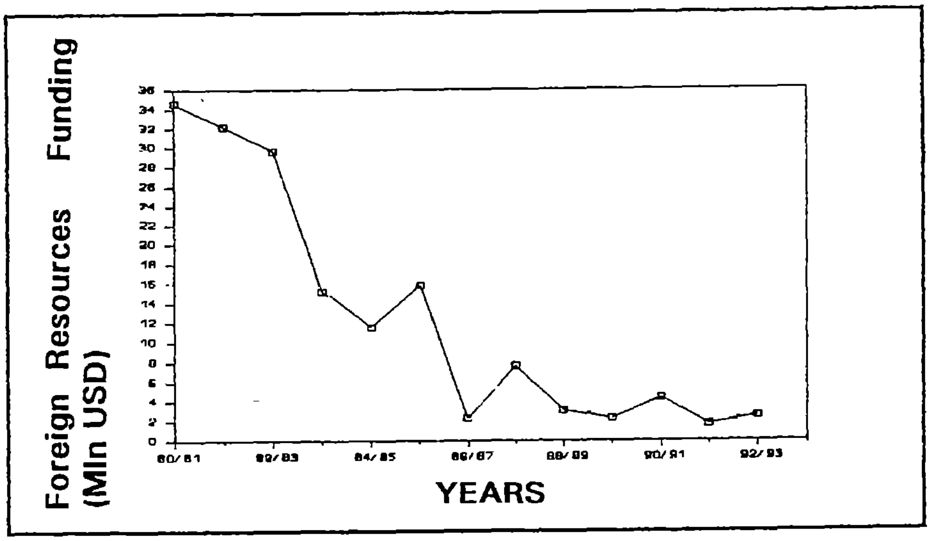

Figure 2: Tanzanian water sector foreign funding..

1.11.4 Conclusions

Possible solutions to problems/constraints related to wider dissemination of more sustainable waste water technologies in the Tanzanian context are:

I) Now that the government has shown willingness to private-public partnership in the water and wastewater sector, the ultimate role of the government should be that of a facilitator, regulator and controller rather than a provider of service.

ii) Future success of the private-public partnership in the expansion and sustainability of the waste water treatment technologies would depend on:

* continued partial financial support for sometime, better performancce of public administration and improvement in mobilization and utilizing public resources;
* a successful institutional management for the co-existence of the parties involved in the new partnership;

* appropriate design of the systems that will address the socio-economic and technological challenges that are site/neighbourhood specific. The question of a fuctional and sustainable small to medium scale that is community based should be addressed.

* strength of imparted sense of ownership of the system by the beneficiaries.

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Appendix I: Highlights of national sewerage and sanitation policy (1987) Tanzania.

Objective

The main objective of the sewerage and sanitation policy is to solve different problems hindering urban dwellers to have proper and hygienic means for disposal of human wastes. Among the problems include those of people not connecting to the sewerage system where it exist, people using poor and unhygienic type of latrines and poor sewerage and sanitation services in general. Another objective of the policy is to ensure the provision of urban drainage, foul sewage and roads (infrastructure) in all peri-urban areas before development takes place. These should be included in the master plans.

Sanitation Policy Requirements

Every urban dweller should have an access to a proper and hygienic means for disposal of human wastes by the year 2000.

The choice of a sanitation system for new housing development shall be based on the existing water supply services and considered in conjuction with the population densities outlined here under:-

a) 0-50 persons/hectre: septic tanks or Ventilated Improved Pit Latrine (VIPL),

b) 50 -100 persons/hectre:- sewerage system

- septic tanks & soakaways pits
- improved pit latrines (VIPL),

c) more than 100 persons per hectre: sewerage system.

All users of sewerage system should pay. Likewise industries are required to pretreat the wastes they produce and be charged for the quantity of sewage and strength of effluent discharged.

All developments in unsewered areas shall require that the owner to construct a soakpit of an approved design for sullage disposal where this does not exist. In areas of high ground water table they shall be required to construct cesspits and shall be emptied when full.

All houses which are at a minimum distance of 30 metres from sewer lines should be connected to these sewers in order to dispose their sewage.

Household in sewerage areas shall be required to connect to the sewers, councils shall extend the service sewer to the property boundary before making it mandatory for the owner to connect to the sewer line. Sewer connections shall be carried out by the engineering department of the city, Municipal or town council or by a contractor approved by the authority.

1.12 Towards effective wastewater management in developing countries: some issues, *Jeremy Parr.*

Water, Engineering and Development Centre (WEDC),
Loughborough University,
Leicestershire, LE11 3TU, UK,
Tel: + 44 115 222618,
Fax: + 44 115 211079,
E-mail: jemery.parr@lboro.ac.uk

1.12 Introduction

Many wastewater management facilities in developing countries under perform or are completely inoperational. This paper briefly discusses some of the reasons why this is so, and why there is difficulty in implementation of alternative options.

Problems with implementation of wastewater management in developing countries:

■ *Low priority on domestic sanitation*
For low-income countries, the public health engineering priority is usually on water supply, as this is the most immediate need. Water supply is often seen as the primary route to health improvements (yet experience has shown that water supply, sanitation and hygiene education are *all* needed).

■ *Low priority on industrial pollution control*
In middle income communities, priority is often on economic growth before environmental protection is considered, and so industrial pollution typically becomes a serious problem.

■ *Expense*
Conventional wastewater management is usually expensive. Both conventional sewerage and wastewater treatment are just too expensive for low-income communities where there is often no municipal incentive for such schemes as there is no tax system in place. Alternative lower cost sewerage systems exist, but are they still affordable. Waste stabilisation ponds are a more appropriate option for most developing countries, but the space requirements often mean they have to be located out of town - which means extra cost of more sewer lines.

■ *Health versus convenience*
Experience at WEDC has shown that on-site sanitation is still viable even for large housing densities. Research has shown that there is not much difference between the health benefits from a pit latrine and a flush toilet. The important point is that broadly comparable health benefits will be there if *any toilet* is provided (and *properly used by all*) in the first place. But 'peer pressure' (I want one of those because he has got one) is a powerful motivator.

■ *Incentives*
Nearly every developing country has a system where Coca-Cola bottles or beer bottles are delivered, on-time, to every corner of the country. Buses and cars are kept going for years past their design life ..... but, wastewater management facilities, if installed, often do not work. There is a lack of incentive to keep them running; they are a drain on resources as they do not show any added value (usually seen in revenue generating terms) to the average person.

Why do unsustainable options continue to be implemented?

Treatment options are usually based on Northern standards of practice - Northern approaches to Northern problems e.g. oxygen demand is seen as a greater priority than pathogen removal. We have all heard of inappropriate processes being built in many locations. But why do they continue to be implemented (and continue to fail)?

■ *A complicated issue?*
Wastewater treatment is often seen as a 'tricky' subject transcending chemistry, biology, engineering, biochemistry, etc. which needs the input of experienced professionals from the North to sort out. So, inappropriate options (facilities which do not work) are often implemented by these experts who are not familiar with the local situation.

■ *Regulation tools*
Discharge standards and other methods of regulation have a great effect on wastewater management. As an example: an Indian Ocean state implemented new consents for all discharges to surface waters. One of the many parameters specified was that no discharge is to exceed a COD of 30 mg/l. There are very few processes which could meet this standard, and to have it for 100% of samples shows a lack of appreciation of the problem. Indeed, it can be seen to be worse than that. In this case industries sought advice as to how to meet this discharge consent. They were told that they would need to build treatment facilities, which had to be of a sophisticated nature to reach this consent level. They were built, but never operated well after commission as the local operators could not sustain this level of technology. The net result is a waste of resources to all. It may be argued that effective wastewater management only comes with effective and appropriate regulation.

■ *Definitions of alternative and appropriate*
Frequently, 'alternative' and 'appropriate' technologies are thought to be inferior - there are problems in the use of words such as these and hence in the adoption of the technologies they represent.

■ *Prestige*
Often, municipal leaders want the latest technology, however inappropriate, so that they are seen to be keeping up with the latest developments.

■ *Corruption*
This is too often an inescapable fact of municipal life. A large costly project means more opportunities for pay-back.

■ *Tied aid*
At the same time, donors may be guilty of forcing inappropriate options on to communities.

■ *Dissemination problems*
New, more sustainable options are being developed. Often, these do not receive widespread recognition as dissemination may be poor and/or slow.

■ *Risk?*
In addition, there may be unwillingness to try out these technologies which may be perceived as being new and untested. Although the technologies may be proven, there may still be a perceived risk on the part of implementors - and hence they may opt for the more established, but unsustainable, alternatives.

■ *Impatience?*
There may also be an issue of impatience - communities may be unwilling to try out a process based on local needs and priorities which may take some time to plan, build or mature when off-the-shelf designs from established (but unsustainable) options may show quicker immediate term output.

1.12.2 The way forward

On the positive side, we can be encouraged by:

■ *Increased health and environmental awareness*
There is a growing recognition by many (including in developing countries) that there is a need for sustainable solutions to these problems (however, the majority of the world's population remain below the threshold where this is of concern to them - to these, survival is the key).

■ *Capable engineers*
Often, the engineering ability of professionals in developing countries is unquestionable. Experience at WEDC has shown that it is the managerial skills which often need to be developed. These local professionals may need training in appropriate technologies, but they also need empowerment to be able to implement them with confidence.

■ *Alternative systems do work*
Perhaps, practically, the only way in which they will gain acceptance is if their applicability is shown by widespread adoption in developed or newly industrialised countries. There may be the potential for this as many regions are now facing both severe water shortages and environmental dangers - water is becoming a severe constraint on development. Hence, systems which reduce or recycle waste and reuse beneficial side products should be on the increase in arid or semi arid regions, or places where environmental protection is becoming necessary for future economic growth (places like California, Australia, the Middle East or the Asian 'Tiger' economies, for example - all of these could be a good lead for other regions to follow).

But,*Some fundamental questions need to be asked*

For example, is (conventional) sewerage *always* a sensible idea - spending alot of money on sending potable water down a pipe to wash along faeces thereby potentially spreading out a harmful substance? Why not use non-potable water - sea water for example? Why not localise the collection, by not using water at all, and hence contain the potential pollution?

1.12.3 Conclusions

It should be recognised that for many communities, the incentive for wastewater treatment remains low. Most people are concerned with survival, and do not understand, or are not in a position to do anything about, the links between poor sanitation and poor health or poor environment. The policy issues are difficult - one needs to ask, who is making the decisions about future investment - and on what basis are these decisions made? Part of the incentive for wastewater management must be seen as the improved asset, giving added value to environmental health. Proper and appropriate regulation is vital to any wastewater management strategy. Many of the tricky wastewater problems in developing countries today are associated with industrial activity.

There is a need for local solutions to local problems, on the basis of sound research and policy formulation. And continued dissemination, training and education are vital.

1.13 Small Scale Urban Waste Water Treatment in Palestine, *Gert de Bruijne*[3].

P.O.Box 51647, 91516,
Jerusalem, Palestine via Israel,
Tel: + 972 2 741770,
Fax: + 972 2 741770,
E-mail: sustfarm@netvision.net.il / gert@baraka.org

1.13.1 Summary

Waste water collection, treatment and re-use have not received sufficient attention of Palestinian urban planners and engineers. Sewage systems were not in demand over the last decades. Village councils simply did not request waste water treatment systems, because the water pollution was not recognized.

Only in urban areas, where during the last years the water consumptions have increased rapidly as a result of regular water supply, municipalities have embarked on large sewerage projects, always funded by foreign donor countries. Until today in most cases the collected raw and semi-treated waste water is discharged in wadis. This practise combined with the traditional use of cesspits prevent the re-use of waste water and contaminates the environment and groundwater. It is estimated that 50% to 60% of the urban sewage is discharged into the wadis without any treatment, it is then frequently used to irrigate market crops.[4]

Most municipalities face major problems concerning sewerage and waste water treatment.[2]

In August last year at a workshop organized by the Water Resource Action Program (former UNDP, recently under the National Water Authorities) major issues and problems regarding wastewater were identified as:[3]

> 1) Waste water is being wasted and mining of groundwater resources, especially in the Gaza Strip, is resulting. Even in the West Ba, where the situation is different, farmers suffering shortages of groundwater to irrigate crops could bebefit by exploiting waste water.

[3] The author would like to thank following people for their comments and suggestions: Nader al-Khatib, Mohammed Said Hmeidi, Abdellatif Mohammed

[4] Palestinian Water Resources; a rapid interdisciplinary sector revieew and issues paper, by: Water Resource Action Program-Palestine, October 1994

2) Both in the West Bank and Gaza strip, some farmers use raw sewage to irrigate crops, even salad and vegetable crops, thereby endagering their own and public health.

3) Lack of provision of effective wastewater collection and disposal systems is causing groundwater pollution through the infiltration of contaminated effluents to the aquifer.

4) Appropriate waste water treatment and re-use technology for the West Bank and Gaza Strip have not been identified and experience in operating systems is very limited. The ability to operate and maintain wastewater treatment systems is in doubt and significant training of personnel will be required in the future.

5) The institutions that are now responsible for the development and management of waste water services are not neccessarily qualified to carry out their functions effectively and there is a lack of coordination among the various agencies involved in the sector.

6) The establishment of the National Water Authority is expected to improve the regulation of water and wastewater but a rational institutional framework needds to be developed.

Few attempts have been made to introduce and impliment low cost small scale WWTSs. Experience, expertise and knowledge about these systems have not been exchange, and efforts to do so are limited to relatievly small group of individuals.

This paper describes the existing waste water treatment systems in Palestine and explains why appropriate technologies have not been used. Finally, it tries to outline what could encourage the dessimination of low cost and small scale WWTS in Palestine.

1.13.2 Municipal - Urban

One should make a distintion between municipal waste water systems and urban waste treatment systems. The latter includes centralized municipal sewerage and treatment operations as well as efforts of individuals and small urban communities to deal with waste water on a household and neighebourhood level respectively.

Both municipal and individual efforts need to be encouraged, but it is important to make the distintion, because strategies to disseminate the appropriate technologies differ according to the target group.

Although it is common wishdom that waste water can become an important resource for irrigation, one should bear in mind that urban re-use has a numebr of advantages over rural agricultural use.[4]

- Most urban water uses are non-consumptive, such as toilet flushing, industrial cooling, irrigation of park and green areas, and urban agriculture. Therefore, can be supplied with lower quality water

- New freshwater supplies need to be carried longer distances to serve urban areas because the more local sources have been fully exploited, where as erclaimed water is generated locally.

- Because urban and industrial demands are not seasonally variable as agricultural irrigation demands, seasonal storage requirements are sharply reduced, thereby reducing evaporative losses.

- Water in urban use is far more valuable than in agricultural use. Therfore, treatment costs are easily recovered than where water is used in agriculture.

1.13.3 Water Resources in Palestine

In Palestine there is only as much fresh water available as is collected from the winter rains. The total volume of renewable fresh ground water in the aquifers under the West Bank, the main water resource, is maximal 450 million m3/year. Palestinians only use about one-fifth of this fresh water. The rest is exploited by Israel. Another 200 million m3 is brackish ground water.

The annual fresh water recharge in the Gaza Strip is about 50 million m3 (irrigation return flow adds 20 million m3/year highly polluted water). The current annual water consumption in the Gaza strip exceeds 100 million m3.[5]

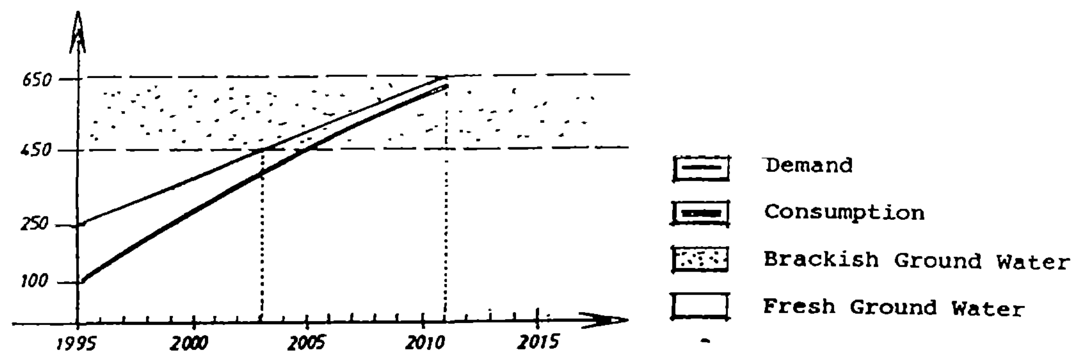

Figure 1: Renewable Water Resources and Water Demand/Consumption development in the West Bank.

This region receives little rain during only a short period for a fast increasing number number of people causing a chronicle water shortage. Experts agree that the demand for drinking water (domestic demand) will rapidly increase. So will the demand for water for industry and tourism. In the future the costs of water will increase tremendously.

The largest consumer of water is the agricultural sector, using roughly 75 precent of total annual consumption. Because municipalities, industries and the tourist sector will be willing and able to pay a better price for fresh water, it is can be expected that their share we increase. Less and at the same time more expensive water will be left for agriculture.

Experts expect that sometime around the year 2020 there will be 15 million people living between the Jordan river and the Mediterranean Sea. At that time no fresh water will be available for agriculture. This is the final stage of a trend and might therefore take longer, but at the end Palestinians, Israelis, and Jordanians as well, have to face this situation.

Althought some people argue that the Palestinian should get all the water under their territory and produce cheap fruits and vegetables for Israel, it is very unlikely that the Israelis will agree to give the Palestinians total control of these water resources. In the future Palestinians we will continue to share water resources with Israel. Like neighbouring countries in other parts of the world they have to come to agreements about their shared water resources.

Even if the Palestinians could use all renewable (fresh and brackish) ground water under the West Bank, again within less than twenty years we they will find themselves in the same situation they are in today. More water is withdrawn from the aquifers under the West Bank and the Gaza Strip than is recharged during the winter months.

1.13.4 Conventional Municipal Waste Water Treatment Systems

- Salfit (collection and activated lagoon)
- al-Bireh (activated sludge)
- Nablus
- Gaza City AL
- Jabalia AL
- Rafah AL

Low cost designs and projects

SDT (Save the Children program, 199-----)
SDT (manual and policy for the Water and Sewerage Authority, 1996)
Facultative Flow Basin (design for Talitha Kumi School, 1995)
Duck weed (design for Jericho Development Society, 1996)
Small bore hole sewerage and sand filters (design for Taffuh, 1996))
Reed bed (pilot research project at Beit Eba, 1994)

1.13.5 Lack of use of appropriate waste water systems

Apart from the SDT programme of Save the Children few small scale/low cost technologies have been applied in Palestine. Though some systems have been designed and are discussed recently, municipalities chose for conventional sewerage and WWTSs. In the rural areas the common sewage disposal systems remains to be the cesspit and pit latrine.

Contrary to the public assumption, islam is flexible when it comes to waste water treatment and re-use. In various Arab countries purity customs have been adjusted in response to local needs and scarcity. In fact, certain Middle Eastern countries have long practices wastewater recycling for agriculture. For 60 years, effluent from Cairo treatment plants has been succesfully used in producing citrus, dates, and pecan. Also in Jordan, Tunisia, Jemen and Kuwayt municipalities and governments have encourged crop cultivation with treated waste water.

The reluctance to regard waste water as an additional water resource is simular to reactions in other non-islamic countries. It can be related to the general lack of awareness about the real dimension of the water crisis and lack of knowledge about principles of waste water treatment. To often Palestinians are not aware of the extent and reasons of ground water contamination. Though in many official publications the severity of the situation have been reported. Especially certain areas of the Gaza Strip ground water pollution is direct danger for the public health.[6]

In discussions with practising Palestinian water & sanitation engineers and planners anumber of reasons for the slow dissemination of appropriate WWTSs were mentioned.

- no awareness and information about low cost technologies among Palestinian engineers
- lack of confidence in technologies that have not proven their efficiency
- few local experience and demonstrations
- even low cost WWTS can be relatively expensive for poor communities for whom environment pollution is not a main concern
- cesspits and pit latrines continue to be the cheapest systems in rural areas
- economic benefits of waste water re-use are recognized
- economic benefits of WWTS have not been demonstrated
- people are not used to pay for waste water treatment and its operation maintenance
- foreign and Palestinian consultancy firms avoid low costs sysems, because the they normally work on a percentage basis.
- the donor agenda

All waste water project are financed by outside donors who allocate the budget first and then asked for a design.

Therefore it is surprising that municipalities who request financial support for waste water treatment are willing to be biased towards the technology of the donor. On their part donor officials are often not familar with appropriate technologies.

National authorities such as the Ministry of Planning and Palestinian Water Authorities did not yet develop adequate political instruments to influence the decision making and interfere in this bilateral relation. For example, the initial costs of the activated sludge treatment of al-Bireh municipality were estimated at 8 milion dollars. Finally the German GTZ was willing to allocate 19 million dollars for the project.

1.13.6 Suggested urban waste water treatment systems

■ *Dual Systems*
Different options for dual water systems have been suggested for communities in the West Bank. Experiences in the US and Japan focus on the use of treated waste water for nonpotable use in urban areas. Others suggest to seperate grey water at source for direct household use (toilet flushing, outdoor cleaning and irrigation).[7] Toilet flushing only uses an average of 40 percent of the daily household water consumption anmd can satisfied with grey water from the same household.

The possibility of centralized municipal water re-use efforts have not yet occured to Palestinian urban planners. However, on the household level one can notice individual efforts to re-use grey water for cleaning and irrigation.

In urban areas where water closets are standard outfit of the sanitation facilities dual systems should become standard as well.

Various low cost small scale grey water treatments have been developed, but very few for immediate household re-use other than garden irrigation.

■ *Septic tanks & small bore hole sewerage systems*
Althought septic tanks have been widely use in rural areas their potential for peri-urban areas whether or not in combination with a small bore hole sewerage systems has not be fully recognized. Especially in mountainous regions where the topography would require expensive conventional sewerage systems, anaerobic pre-treatment allows the use of cheaper sewerage systems.

■ *Reed Beds*
In Palestine natural reed beds as well as 'man-made' reed beds can be find. The latter have developed naturally at places where raw or semi-treated waste water is discharged. In 1994 a pilot project was implemented at Beit Eba in the northern part of the West Bank to evaluate the performance of reed beds (with local Heleocharis Palustris (L.) R.Pr.) and the farmers acceptance of and willingness to use the treated waste water for iffirgation.

The general conclusion of the reseracher was that reed bed systems can offer economical, environmentally sound and socially accepted technique of water water treatment.[8]

■ *Duck Weed*
Various visiting consultants have suggested the use of duck weed for waste water treatment, and as a fodder production for poultry. Local Palestinians water experts are completely in experience with this technology as duck weed like most water plants are not indigeous in Palestine.

Recently, a pilot project have been designed to use duck weed to treat waste water from a dairy farm in Jericho. So far it is unclear whether the main objective of the project is to produce fodder or produce effluent for irrigation.

■ *Sand filters*
Officials of the Environmental Planning Directorate of the Ministry of Planning are in favour of sand filtration as waste water treatment for small communities. In the case of the village Taffuh near Hebron they did insist on use of small bore hole sewerage and sand filtering as secondary treatment (household septic tanks as primary treatment) for a low-cost sewerage and waste water treatment. The project is currently under design by a local consultancy firm, but depends also on external input from a US consultancy firm.

■ *Irrigation with saline water*
Since a number of years researchers in Israel are improving and developing crop varieties that are saline-resistant.

The results, in particular of saline-irragation of tomatos and melon, are encouraging and would mean that saline grey water can be used on a wider scale than before. This opens new possibilties for household urban agriculture.

■ *Rotation*

1.13.7 Criteria for sustainable waste water treatment in Palestine

- users should feel a sense of ownership and responsibility over the system
- operation staff and technicians should undertstand the principles and functions of the system
- WWST should be based on available local technology and expertise
- users should at least be able to pay the operational costs of the WWST

1.13.8 Waste water policy recommendations

Integrated waste water policy

- □ awareness about water scarcity and pollution, and the benefits of waste water treatment
- □ demonstrations of small scale water treatment systems for various different locations
- □ pilot project related to economic benefits (irrigation)
- □ development of local expertise through training, workshops, publications, interregional information exchange, site visits etc.
- □ policy guidelines and standards

Water treatment and re-use on household level is a responsibility of individual house owner, as well as the local authority.

As public awareness about the developing water crisis will increase, we can expect that social-cultural attitudes towards waste water treatment and re-use will change. The policies of local water authorities have to meet these concerns and encourage and facilitate public participation.

In order to pursue people to take action to use appropriate technologies they have to be convinced that:

- □ the environmental dangers are real
- □ appropriate technologies work
- □ appropriate WWTSs can be financially benefial
- □ the water and environmnetal authorities are willing and able to support private initiatives
- □ the authorities are serious about enforcing their policies

Assuming that the local authorities are willing to take the responsibility to achieve these objectives their waste water policy should include five elements.

a. <u>public awareness development about the dangers of ground water pollution</u>

partners: PWA; NGOs; professional associations; educational institutions; media
internal responsible: PR department

- development for information material for different groups: health workers, engineers, architects, agronomists, schools, general public
- local water authorities should concentrate on the technical issues

b. <u>septic tank system demonstration and experimental sites</u>

partners: educational and research institutions; public institutions
internal responsible: waste water unit and water conservation unit

- □ Open operating waste water treatment sytems in the West Bank for the public to familiarize itself with these technologies. Local water authorities should be in the position to arrange organized visits to these places.
- □ Establishment of several demonstration sites for small scale waste water treatment and re-use methods with an experimental character, that are open to the public.
- □ Intensify working relations with scientists in order to strengthen the professional capacity of local water authorities

c. <u>develop water and sewage tariff policy that reflects the real costs of water</u>

partners: accountant office/consultant bureau
internal responsible: financial and PR department

- □ To develop a tariff policy that encourage people to save fresh water and re-use waste water
- □ Water and sewage disposal tariffs should include costs of investments, mining, operation, maintenance, depreciation, opportunity and development
- □ The tariff system should allow every household a basic minimum quantity of water

d. institutional development to support waste water policy

partners: external professionals
internal responsible: management and sewage and water conservation unit

- Establishment of a waste water unit which main task is to provide technical advise to the water authorities and technical assistance to the public concerning treatment, re-use and disposal of waste water
- Establishment of a water conservation unit which main task is to provide technical advice and assistance concerning method to make best use of the avalable fresh water resources
- In order to develop these units, either as part of the water authorities or as independent service providers, identification of training posibilities is essential

e. legislation and enforcement to protect the environment

partners: municipalities; engineering association; PWA; police
internal responsible: legal advisor and appropriate units

- The protection of the environment, public health and natural resources (water) should be facilitated by municipal regulations and a permit system for building, industrial and agricultural production, zoning and city planning
- Municipal departments and police forces should actively participate to enforce the regulations and permit system
- External expertise should be involved to help to develop effective systems of regulations and permits

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8 Said Hmeideh

Part 2: Workshop

2 Workshop

2.1 Workshop set-up

2.1.2 Background

In many rural and urban areas across the globe, the availability of fresh and clean water poses an increasing problem. Reasons for this are low rainfall patterns, rapidly increasing demand due to population growth and accelerated urbanisation, and pollution of available resources.

To prevent the pollution of the available water resources it is necessary to treat waste water. Especially in urban areas where accumulated waste and disposal problems result in pollution of water streams and ground water rendering it unsuitable for use in household or agriculture. These problems are generally approached in a traditional way. As sustainability is not included in decision making the solution tends to be conventional.

The design of conventional systems is based on the concept of an end-of-pipe technology. Discharging effluent to surface water without considering possibilities for reusing the valuable resources, water and nutrients. As regulations are getting stricter more and more capital intense systems, using energy and chemicals are designed. In many cases these systems produce sludge which is unsafe for reuse as it contains heavy metals and other toxic compounds.

As conventional systems are not sustainable there is an increasing demand for alternative waste water treatment systems that are:

- requiring a minimal investment
- easy to operate and maintain
- adapted to local conditions
- occupying as little land area as possible
- able to produce a high quality effluent, safe for reuse in agriculture
- able to minimize the production of waste
- able to recycle nutrients in the form marketable products like methane and fertiliser

The concept behind these systems is to approach waste water as an resource rather than a waste. Waste water treatment will no longer be an end-of-pipe technology but it becomes a cost effective utilisation of resources.

2.1.2 Objective

The objective of the workshop was to identify in a participatory manner the existing constraints to the wider implementation of sustainable waste water treatment systems and to identify possible ways to overcome these constraints.

2.1.3. Methodology

The workshop comprised the following elements:

- presentation of papers on alternative waste water treatment systems
- analysis of constraints (problem identification)
- identification of ways to overcome the existing constraints (objective formulation)
- selection of potential follow-up projects

Papers were chosen that cover a wide range of aspects as the intention was to show that there are various different options to achieve more sustainable waste water treatment. Considering the importance of non-technical aspects a paper on institutional aspects was included. Due to the limited time available other non-technical aspects like policies and private sector involvement were only addressed briefly.

The central part of the workshop was formed by problem identification. Through brainstorming the participants made an inventory of the actual problems causing the core problem: "more sustainable waste water treatment systems are not widely implemented". All actual problems which came up were written down, clarified, and grouped.

Due to lack of time it was not possible to establish cause effect relationships in a participatory way with the whole group. Therefore the moderator drafted the cause effect relationship which was presented for further discussion. The final result was the problem tree as described in paragraph 2.2.1 and appendix 2. It should be stressed that the problem tree can only be well understood in the light of the discussion from which it originated (paragraph 2.2.1).

In the discussion, special attention was given to the definition of sustainability to emphasize that this term includes not only environmental issues but also social and economical issues. An inventory of unsustainability factors of waste water treatment systems was made (appendix 1.).

Brainstorm and discussion were also the basis of the objective formulation (paragraph 2.2.2). Thereafter, the participants agreed to work out project ideas in two separate groups. One group focussed on information and education, while the other group focussed on the demonstration of existing technologies In a final session the project ideas were presented to the whole group of participants for further discussion. The final project ideas are described in paragraph 2.3.1 .

Note: the original workshop programme is inserted in appendix 4

2.2 Discussion

2.2.1 Problem Identification

More sustainable waste water treatment systems disseminate slowly. Although these systems have many advantages investors are mainly focussing on conventional large scale waste water treatment systems. There is no interest in changing to new waste water treatment technologies as there are vested interest in conventional systems. Furthermore there is a reluctancy to change based on a lack of awareness due to lack of information and promotion, pressure from interest groups, and institutional support.

Vested Interest

There is a mutual complicity at development bank and consultant companies, they are biased. The waste industry is making money Leading organisations push expensive conventional systems in their interest. Innovations that are not yet proven will not be introduced. For instance in the Netherlands we will have to rethink the centralised system structure as it is very expensive and not sustainable to serve the last 5% of the population not yet sewered.

Who is going to push small alternative systems? To get alternative systems implemented there should be an infrastructure but this will take some time.

Awareness

Lack of promotion leads to a lack of awareness For instance the lack of North-South and South-South correspondence makes it difficult for new technologies to disseminate. As such the impact of a demonstration project will be limited to a relatively small area.

Another factor leading to a lack of awareness is the lack of information. As little information on alternative waste water treatment systems is disseminated people wonder whether alterative systems are a proven technology, whether these systems are suitable and whether these systems are affordable.

■ *Alterative systems a proven technology?*

There is a general feeling that alternative systems are not yet state of the art. More full scale demonstration projects are needed to increase dissemination of alternative waste water treatment systems. Evaluation and monitoring of such pilot projects are needed to provide information on the performance of the technology. Detailed information on health and environmental aspects and on cost and benefits is needed to make a good comparison of the different systems possible. Alternative systems need more fundamental research as not all of them seem mature technologies. Furthermore there is no structure behind alterative systems to deal with technical standards, designs manuals, regulations, monitoring, quality control etc..

■ *Alterative systems suitable?*

For waste water treatment in developing countries control of pathogens is the main issue as still many people suffer from water related diseases. To prevent the spreading of diseases it is very important to provide clean drinking water and to operate a waste water treatment system with high pathogenic removal rates. One should realise that fear of diseases creates an attitude anti the reuse of effluent. Furthermore it might socially and culturally not be accepted to reuse waste water. Therefore, it is important to evaluate health aspects related with reuse of effluent and sludge. Such problems should be resolved in close discussion with the end users.

Alternative systems focus on the treatment of domestic waste water, but it is difficult to separate domestic and industrial waste water. The terms 'Municipal' and 'domestic' are misleading because small industries might be operating in domestic areas. Industries should take responsibility for treating it own waste water but alternative systems should be able to treat existing waste water flows.

■ *Alterative systems more expensive?*
The financial structure of sewerage and sanitation management is often a problem. The structure is complex as municipalities, the government and end users are involved. Sewerage is expensive, different priorities might result in no sanitation facilities at all Waste water treatment does not have to be cheap but it has to be affordable On-site waste water treatment is in principle more affordable as long pipe systems are not required. Small scale waste water treatment is not putting the costs on the shoulders of the whole community, the user who pays also benefits from the reuse in gardens or on farms. End user participation is another reason to chose small scale waste water treatment systems, as a top-down approach with participation from the end user will increase the willingness to pay. Although it is often a misconception of local governments to believe that people do not want to pay, on the other hand, people not willing to pay are hard to disconnect.

The financial benefits should get publicity to attract more private funding. It would be interesting to identify opportunities to use alternative systems for the treatment of waste water of small scale micro enterprises.

Finance is an important issue in technology selection, price is a key in decision making. Economics should be even more important as it also includes environmental and social costs and benefits. Life cycle cost analysis might be a useful tool in comparing different systems. Including environmental costs and benefits emphasises the advantages of more sustainable waste water treatment systems.

Institutional support
There is a bias in decision making at different levels. Decision makers like politicians, consultants and engineers, are suspicious about new technologies. Conventional systems are established and new alternative systems should prove themselves before they are implemented. There is no room for improvement through failure

Local decision makers seem to want conventional systems at high cost. Expensive may be associated with quality, conventional is what they know, and what they have seen on their trips to industrialised countries Most decision makers are trained in Northern countries. In a way they may have the wrong kind of expertise. Furthermore, conventional systems are thought to be a safe choice as there is local expertise with these systems.

The traditional thinking of politicians results in regulations which are supports conventional technologies, while regulations should lead to a more sustainable development path Regulations that stimulate the reuse of resources will promote alternative waste water treatment systems.

There are also some political conflicts frustrating effective waste water treatment planning:

- Municipalities tend to think small, while governments tend to think big

- Donors may want to invest the donated money in waste water treatment systems from the donor country.
- In local governments there is often a lack of coordination between sub-sectors like waste, drainage, health, housing, local institutions etc..
- Different actors have different time horizons. For instance municipal governments are biased to plan for only four years as this is their political term. While sustainable waste water treatment needs a long term view. For waste water treatment plants in general life cycles of 20 years are accounted for. Therefore, it may take a long time to introduce new technology.

Decision makers like politicians are informed on possible solutions for waste water treatment by engineers. Engineers may not take up new technologies as education tends to be old-fashioned. Furthermore, the lack of a multidisciplinary approach may result in neglecting social and cultural aspects.

The first step towards finding a solution should be an analysis of the problem, in case the of waste water treatment this would be in the local situation. However, in many cases finding a solution starts from a technical orientation.

Possibly the reluctancy to change might be overcome by starting with alternative systems which do not differ too much from the traditional ones.

Interest groups: End users

The attitude of water users is important as they are the ones who pollute, and they are paying for waste water treatment services either directly or indirectly The large distance between water users and the treatment of their waste results in lack of awareness and an irresponsible attitude. Water users are not aware of the effect of waste water on the environment, health nor are they aware of the possible solutions. Often water users are not uninformed and not asked to participate in the decision process.

Awareness of end users could create a local dialogue in which politicians could be influenced by end users. Overall effectiveness and lack of transparency of governmental institutions makes it difficult to influence the decision making.

2.2.2 Objective formulation.

2.2.2.1 Inventory of possible solutions

To overcome the constraints identified in the problem analysis discussion possible solutions were identified. Projects addressing the following points would help in wider dissemination of alternative waste water treatment systems

Vested interest / Technology:

- *change design concept to waste as resource*
- *realise that there is not one single solution*
- *alternative waste water systems should be developed/proven on a wider scale*
- *need for more evaluation and monitoring as well as dissemination of information*
- *technological comparison*
- *prototype development in several countries*
- *identify niches for technology*
- *support micro enterprises to use alternative waste water treatment systems*
- *technology transfer & marketing*

Awareness / Information:

- *promotion of technologies*
- *resource centre*
- *network analysis and linkage*
- *sending proceedings to decision makers*
- *waste water discussion on the Internet*
- *making information accessible*
- *textbook on alternative systems not too technical*

Institutional support.

- *lot of decision makers are biased or have a hidden agenda*
- *policy changing*
- *strategy development on integrated waste water development*
- *promote alternative regulations leading to more sustainable development*
- *exchange of ideas with key persons*
- *education of decision makers at all levels*
- *financial problems on funding and cost recovery*
- *obtain cost analysis data*
- *private sector involvement*

Interest groups / End user participation:

- *Social aspects like participation, acceptance and attitudes require more attention*
- *under presented are social scientists - interdisciplinary approach*
- *multi-disciplinary promotion and education*
- *education of engineers*

Education & information and technology demonstration seemed the keys to solution. As such the formulation of project proposals was based on these issues.

2.2.2.2 Discussion on education & information

Constraints for the widespread implementation of alternative waste water treatment systems are:

- discussion makers and engineers are biased because they lack information on these systems.
- engineers lack expertise and information to construct the systems
- users of treatment systems lack information and have no confidence in alternative systems

Stakeholders must be informed about possibilities and benefits of alternative systems. Engineers should have access to education in construction and implementation of these systems. In order to achieve dissemination of knowledge on alternative systems the following basis for a plan of action was formulated:

A Target group
1. Experts (town planners, engineers)
2. Members of the community (end-users)

B Sort of information
What type of information would be useful for both targetgroups?

2.2.2.3 Discussion on technology

Different alternative waste water treatment systems should be tested in different locations in such a way that comparison is made easy. People with a need for alternative waste water treatments systems should be linked with people who have the knowledge of these systems and with people who are willing to fund. Important issues in this discussion were the type of technology, land area, scale, monitoring, and costs.

Technology type:
Two types of technology were distinguished:

1 Sustainable sewerage treatment
All technologies which are able to treat waste water in a sustainable way. Water treated by this type of technology can be safely discharged into surface water.

2 Integrated resource use
Technologies of this type optimize resource recovery locally. The waste water is seen as a valuable input of resources that can be used in agriculture and aquaculture.

The "integrated resource use" technologies have the advantage water and nutrients are recycled locally. Ecological problems with too many or too little nutrients in a certain area can be prevented. However it might not always be possible to implement this kind of technology. Land area available but also social and cultural aspects can be crucial in deciding which technology is appropriate for a certain situation.

Land area:
Land area is an important variable especially in densely populated urban areas. The price of the land is an important factor in the cost of a waste water treatment systems. One might suspect that alternative waste water treatment systems occupy more land than so-called 'high

tech' traditional systems this seems untrue. The integrated farming system as presented by George Chan occupy 1 m^3 per person. Systems like the one discussed by Jesus Arias Chavez can also be built very compactly, and might even be constructed on a roof if no land is available. One should also note that the land used for the construction of a waste water treatment system is preferably situated low so that waste water can be transported by gravity. In most peri-urban areas low lying waste lands are available.

Scale:
Due to rapid urbanisation there is an urgent need for sustainable waste water treatment systems, especially in peri-urban areas. When addressing the waste water problem in urban areas there are two scales of interest: small scale onsite treatment and medium scale. Large scale systems seem inappropriate as they need a very expensive tubing system.

Monitoring:
A monitoring programme must be formulated to make sure that monitoring is standardised to make comparison possible. Therefore indicators that should be measured 3 times a week by taking a composite sample over a day are:Flow, BOD_5, COD_{total}, $COD_{soluble}$, FC_{total}, N, P, S, K, Cl^-,S^{2-}, TSS total suspended solids, VSS volatile suspended solids, pH, Temperature, EC electric conductivity, Heavy metals, and if present Grease/Oil/Surfactants etc.

Total life cycle cost:
As costs are always an important key in decision making they should be monitored in such way that comparison is easy. Therefore the total life cycle cost should be calculated using the real costs over 20 years, a real interest rate (as a norm 10% seems reasonable, note: real in this case means corrected for inflation). All important costs should be specified like: land, energy, gas, and sludge disposal. Externalities and environmental benefits should be quantified as much as possible, and assumptions made should be clearly mentioned. This is very important in competing with traditional systems. For comparison life cycle cost per kg BOD removed or per capita/year or per m^3/day can be used

2.3 Output

2.3.1 Project proposals

E-mail network

Objective: Creating a world wide network of experts on sustainable waste water treatment for dicussion, information sharing and correspondence.

Plan of action: Setting up a network on GARNET using e-mail.

Parties involved:
- Jemery Parr of WEDC will initiate the network.
- WASTE is willing to pay a coordinator from the South for the first year on part-time basis (one day a week).
- Herbert Aalbers volunteered to be interim coordinator.
- ARMSA a non governmental organisation in Guatemala will provide a Spanish perspective to the English discussion.
- All participants of the workshop will be member of the network and should take the initiative in starting discussions and share information.

Coordination:
- WEDC and WASTE

World wide demonstration

Objective: Demonstration of sustainable waste water treatment technologies as solution to the waste water problems in urban areas.

Plan of action: The project aims to have demonstration projects of different types and scales of technologies. The project should have a global coverage because the impact of demonstration is local. Therefore demonstrations should be held in at least 4 regions of the world; Africa, Asia, Latin America, and Netherlands/USA. Per region different technologies should be demonstrated to compare not only the technologies but also to find optimum scale and settings for the local conditions. The project should built on knowledge already available. For systems already in operation a monitoring project should be implemented to make comparison with other technologies possible. To make a proper comparison a handbook will be written in which is the minium monitoring required is defined, technical as well as economical.

A working group should:
- □ make an inventory on existing systems in operation,
- □ write the handbook on monitoring,
- □ and provide initial site selection/identification.

Parties involved:
- WAU
- WASTE
- George Chan
- Centre of alternative technologies UK
- Bill Jewell
- ARMSA/URURAL
- Rob Lichtman
- Xochicali.

Coordination:
- ETC

Book

Objective: Dissimation of existing knowledge on alternative systems.

Plan of action: A textbook on alternative waste water treatment systems which contains:

- Overview of other books.
- Alternative waste water treatment systems (proven technology); design criteria, technology descriptions of existing systems including integrated systems, information costs, operation and maintenance guidelines, details on performance of existing systems etc..
- Implementation aspects; constraints and problems one can come across including institutional organisation, social and cultural aspects.
- Guidelines for the choice of systems.

The book should be very practical and detailed. Users should be able to decide which system is most appropriate in their own specific situation. The book should not too technical in order to stimulate a multi-disciplinary approach in waste water treatment

Parties involved: Participating in the editorial team which will write the project proposal:

- WEDC
- WAU
- Xochicalli
- Gert de Bruijne

Coordination:

- ETC

Short courses

Objective: Providing education on alternative waste water systems.

Plan of action: A "travelling training circus" will go around the world to provide practical short courses on alternative waste water treatment systeme The courses will focus on the regional conditions and will be in the local language. A coordination team will start with the development of a curriculum and the search for resource persons who have a lot of field experience.

Parties involved:
- IHS
- IHE
- WAU
- WEDC
- University of Chapingo

Coordination:
- IHS and IHE

Video documentary

Objective: Showing alternative solutions to common problems.

Plan of action: The video should focus on education and not on technical details.The production will be low profile and low cost.The video will be translated in several languages. Local proposals are demanded via the network

Parties involved:
- Local counterparts
- Donors for co-financing

Coordination:
- WASTE

2.3.2 Commitments and statement

The formal commitments made during the workshop are shown in the box.

Box 2: Commitments.

1. E-mail network discussion group will be set-up (WEDC and WASTE)
2. ARMSA will function as a Spanish Language Note
3. WEDC will start up the discussion group under GARNET
4. Herbert Aalbers offered to function as interim coordinator (if necessary)
5. WASTE will fund a part-time coordinator from the South
6. All participants will contribute to the discussion in order to make it successful
7. ETC will coordinate the follow-up to this workshop
8. All participants will receive the group-photo taken during the workshop
9. Formal proceedings of this workshop will be available before the end of February 1997

At the and of the workshop the following statement was formulated :

A group of professionals, from 17 different countries, who are concerned about waste water management met in Leusden to discuss the constraints in implementing a more sustainable waste water treatment. The discussion revealed that there are promising examples of innovative technologies which are more sustainable than conventional technologies.

The group of professionals concluded that in order to come to implementation of the more sustainable technologies there is a need to disseminate information on these technologies, to promote these technologies. Furthermore it is important to continue the development of appropriate technologies and management systems geared at integrated waste management as well as resource recovery and productive utilisation of resources.

The group agreed to:

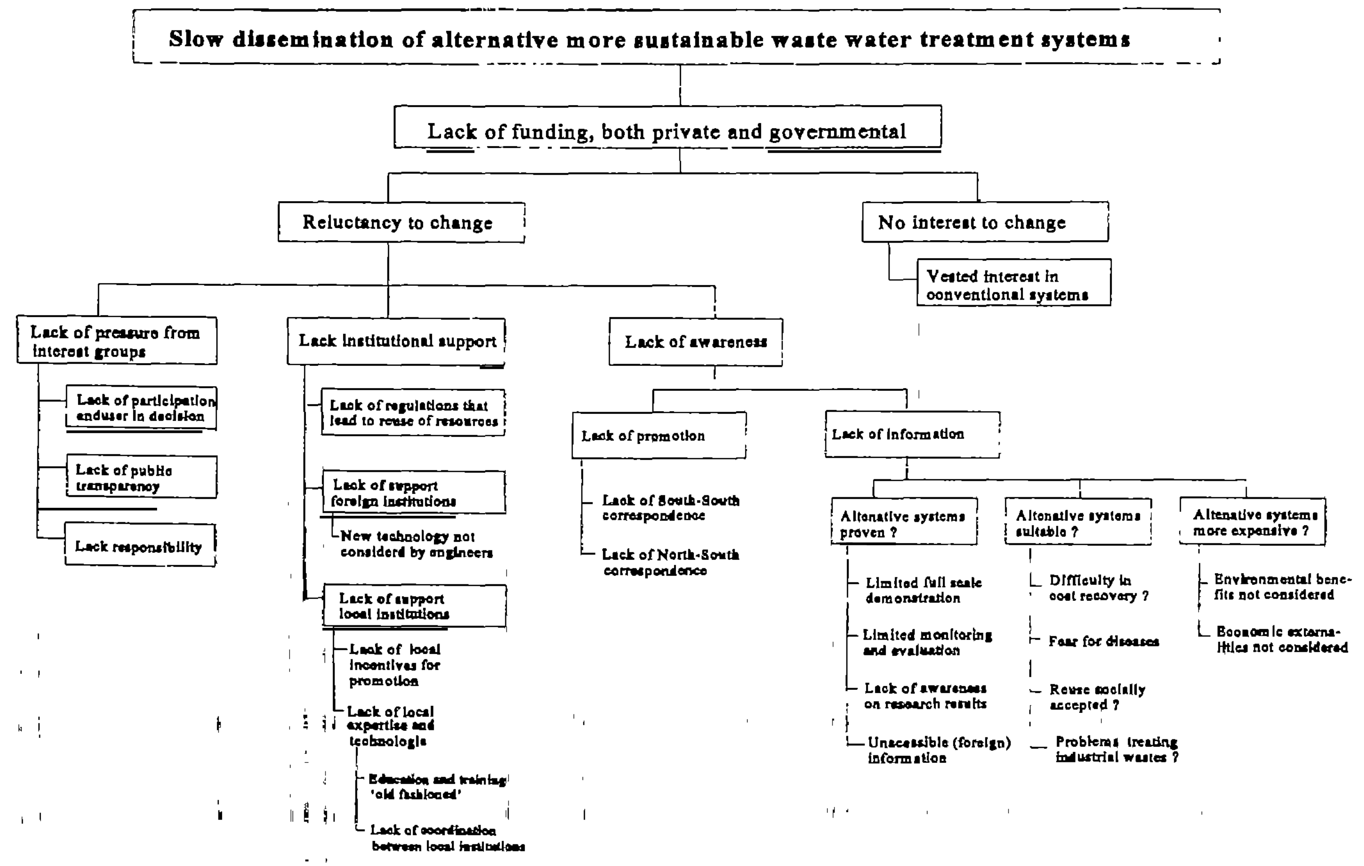
- *Form a network for exchange of information for discussion.*
- *Propose and promote the realisation of a full scale demonstration of more sustainable waste water treatment systems in all continents.*
- *Standardise monitoring of existing and proposed waste water treatment systems.*

Appendix 1: Unsustainability factors

Special attention was given to unsustainability factors to highlight that sustainability is not only an environmental issue but includes also social and economic aspects.

* Production of solid wastes
* Emissions to water
* Emission of toxic substances (heavy metals, organic micro pollutants etc)
* Environmental health risks (health of people, animals, plants)
* Low potential for recycling and reuse of materials
* Use or damage to resources (raw materials, energy, nature, space)
* Use of chemicals
* Energy consumption
* Short lifetime of treatment systems
* Ridged design
* Lack of promoters
* Lack of operational data
* Technical vulnerability and lack of reparability
* Vulnerability of failure by institutional problems, social/economical disruption
* No adequate cost recovery
* Complex and skill or time intensive operation
* Requirement for professional expertise and skills (all levels)
* Level of organisation required
* Institutional and managerial requirements
* Lack of possibility for end users participation
* Cultural unaccepted

Appendix 2: Problem tree



Appendix 3: List of participants

Aalbers, Herbert	Wageningen Agricultural University	Netherlands
Abusam, Abdella	Student	Sudan
Ahmed, Rehan	Pollution Control Services	Pakistan
Ancheta, Christopher C.	CAPS	Philippines
Balkema, Annelies	Technical University Eindhoven	Netherlands
Barrientos, César	ARMSA/URURAL	Guatamala
Blanco, José Maria	BUN, MRSD	Costa Rica
Bruggen, Hans	IHE	Netherlands
Bruijne, de, Gert		Palestine
Buuren, van, Joost	Wageningen Agricultural University	Netherlands
Bijlmer, Joep	DGIS-DRU/UO	Netherlands
Chan, George	United Nations University	Mauritius
Chaves, Jesus Arias	Xochically	México
Diarra, Mamdou Sanata	Ecole Nationale des Ingenieurs	Mali
Frijns, Jos	IHS	Netherlands
Heijndermans, Enno	ETC	Netherlands
Jansen, Marc	IHS	Netherlands
Jewell, Bill	Cornell University	USA
Joode, de, Martine	Xochicali	Netherlands
Leeflang, Sietz	de 12 Ambachten	Netherlands
Lettinga, Gatse	Wageningen Agricultural University	Netherlands
Lichtman, Rob	Advisor	Switserland
Mgana, Shaaban	UCLAS	Tanzania
Mwanga, Jasper Kirango	DSSD	Tanzania
Parr, Jeremy	WEDC	UK
Pujol, Rosendo	Escula de Ingenieria Civil	Costa Rica
Rijnsburger, Jaap	WASTE	Netherlands
Rijssenbeek, Winfried	ETC	Netherlands
Seghezzo, Lucas	National University of Salta	Argentina
Strauss, Martin	SANDEC	Switserland
Vargas, Juan Rafael	Universidad de Costa Rica	Costa Rica
Veenstra, Siemen	IHE	Netherlands
Vleuten, van der, Frank	ETC	Netherlands
Yanez, Fabian A.	CONAM	Equador
Zakaria Amin, Tamin M.	DGHS/DOPW	Indonesia

Appendix 4: Workshop programme

12 November 1996

09:00 - 09:30	Registration
09:30 - 09:45	Opening of the workshop by the chairperson of the day
09:45 - 10:00	Word of welcome by Harry Buikema, Director of ETC Netherlands
10:00 - 10:30	Coffee break
10:30 - 10:50	Paper presentation by Siemen Veenstra (IHE): Overview Waste Water Treatment systems
10:50 - 11:10	Paper presentation by Jesus Arias Chavez (Xochicali): Alternative systems
11:10 - 11:30	Paper presentation by S. Leeflang (De 12 Ambachten): Helophyte filters
11:30 - 11:50	Paper presentation by Jos Frijns (IHS): Institutional aspects
11:50 - 12:10	Paper presentation by Bill Jewell (Ind. Consultant): Integrated WWT systems
12:10 - 12:30	Paper presentation by George Chan (Un University): Decentralised Wastewater Treatment in the tropics
12:30 - 13:00	Discussion
13:00 - 14:00	Lunch
14:00 - 16:00	Problem identification (moderator: Enno Heijndermans) *What are the main constraints for implementation of alternative municipal waste water treatment systems?*
16:00 - 16:30	Coffee break
16:30 - 17:00	Summary and conclusions by the chairperson of the day

13 November 1996

09:00 - 09:20	Opening of the workshop by the chairperson of the day
09:20 - 09:40	Paper presentation by Fabian A. Yanez (CONAM): Pond Treatment Technology in Latin America and Private Sector Involvement
09:40 - 10:00	Paper presentation by Joost van Buuren (WAU). UASB technology
10:00 - 10:20	Paper presentation by Jaap Rijnsburger (WASTE): System scales
10:20 - 10:50	Coffee break
10:50 - 11:10	Paper presentation by Martin Strauss (SANDEC): Treatment of Sludges of Non-Sewered Sanitation Systems
11:10 - 11:30	Paper presentation by Shaaban Mgana (UCLAS): Problems and Constraints
11:30 - 12:00	Discussion
12:00 - 13:00	Continuation of Problem Identification (moderator: Enno Heijndermans)
13:00 - 14:00	Lunch
14:00 - 16:00	Objective formulation (moderator: Enno Heijndermans) *What needs to be done to overcome the identified constraints?*
16:00 - 16:30	Coffee break
16:30 - 17:00	Summary and conclusions by the chairperson of the day

14 November 1996

09:00 - 09:30	Opening of the workshop by the chairperson of the day
09:30 - 11:00	Brainstorming and discussion on plan of action
11:00 - 11:30	Coffee break
11:30 - 13:00	Continuation of discussion on plan of action
13:00 - 14:00	Lunch
14:00 - 15:00	Conclusions and closing of the workshop