Martin Strauss

Food from waste

Human excreta and wastewater can be used to provide substantial amounts of nutrients for plants and fish so long as measures are taken to avoid the dissemination of pathogens.

The recycling of excreta and wastewater has been practised for many centuries. Particularly in Asia, excreta are important in agriculture, fish farming and aquatic vegetable production. In rural China, for example, excreta are used as a soil conditioner and fertilizer. In the hill areas of Java (Indonesia), excreta are traditionally used to fertilize fish ponds. Some of the excreta collected from household bucket latrines in Indian cities are applied by farmers to nearby fields, a practice presenting a serious health risk. However, safety can be achieved through extended storage of excreta from latrines with two pits or vaults for dry or wet disposal. In Viet Nam, "dry" double-vault latrines were introduced several years ago and are now in widespread use. They are also gaining popularity in Central America. "Wet" double-pit pour-flush latrines are an important component of urban sanitation programmes in India.

The use of wastewater in agriculture and fish farming began with the development of flush toilets and sewerage technology more than a century ago. Wastewater from many European cities was applied to nearby farmland, this being the most economic method of disposal. However, as the amounts of wastewater increased, particularly after the Second World War, the availability of land for this purpose decreased. Furthermore, cheap chemical fertilizers came on to the market. Energy- and machinery-intensive methods of wastewater treatment were developed. Most of the sludge produced in sewage works is still used on the land, but in urban areas this practice has become problematic because too much sludge is produced in relation to the available surfaces. Moreover, some sludges have proved unsuitable for agricultural use due to the presence of heavy metals and persistent organic substances.

It should be noted, however, that in developing countries the geographical, climatic and economic factors determining whether wastewater can be used on the land differ greatly from those in most industrialized countries. In fact, the agricultural use of wastewater is rapidly gaining popularity, particularly in arid and semi-arid regions, for the following reasons:

- scarcity of water for irrigation;
- increased need for domestic water;
- expansion of agricultural production;
- high cost of mineral fertilizers;
- few health risks and little damage to soil if precautions are taken.

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Table 1. Some ways in which wastewater and excreta are used

Continent/ country	Town or area	Waste used	Crops irrigated/produced	Approximate area irrigated (ha)	Organizational, institutional
The Americas					
– Argentina	Mendoza (city)	Primary effluent (at times diluted) and dried sludge from sewage works	Lettuce, onions, tomatoes, artichokes	2000	Provincial government responsible for sewerage, sewage treatment and main irrigation structures; users' associations issue water rights and responsible for secondary irrigation structures; no crop restrictions.
– Chile	Santiago (Zanjón de la Aguada)	70% of city's wastewater (untreated or at times diluted by storm-water runoff)	Lettuce, cabbage, celery, cereals, grapes	6000	Ministries of Public Works, Health and Irrigation responsible for planning, implementation, control of sewerage and main sewage distribution; land owners entitled with water rights; users' associations responsible for secondary distribution; crop restrictions partly effective.
– Peru	Country as a whole	Wastewater (treated, partly treated or untreated)	Miscellaneous edible and non-edible crops	5000–6000	Ministries of Agriculture and Health issue permits to use wastewater.
	San Martin de Porras (Lima)	Wastewater (untreated)	Tomatoes, radish, spinach fodder and non-edible crops	1500-2000	Not organized, but occurs due to lack of fresh water.
	Ica (Cachiche)	Primary pond effluent	Cotton, maize, grapes	400	Crop restrictions effective.
– Guatemala	Rural areas	Stored excreta from dry, double-vault latrines	Maize, miscellaneous vegetables	Not known	Farming families.
– Mexico	Mezquital Valley (State of Hidalgo), Rural Development District 063	Wastewater from Mexico City (untreated, diluted or impounded)	Maize, wheat, oats, green tomatoes, chillies, fodder	58 000	Ministry of Agriculture and Water Resources distributes wastewater, issues permits to farmers and enforces crop restrictions.
	Mexico City	Secondary effluent	Parks and green belts	Not known	Department of the Federal District responsible for sewage collection, treatment and use.

Table 1 (continued)

Continent/ country	Town or area	Waste used	Crops irrigated/produced	Approximate area irrigated (ha)	Organizational, institutional
The Americas (continued)					
– USA (California)	Bakersfield	Wastewater: effluent from aerated lagoons	Barley, field corn, cotton, pasture	2000	Regulatory agency: through regional water quality control boards.
	Irvine	Wastewater: effluent from tertiary treatment plant (includes filtration and chlorination)	Tomatoes, chillies, asparagus, broccoli, cauliflower, sweet corn, citrus orchards	> 5000	Contractual agreements between municipalities and effluent users; health criteria enforced by state health department.
Europe					
– Federal Republic of Germany	Braunschweig	Wastewater (mixed 90% secondary effluent + 10% raw) & sewage sludge	Cereals, sugar beets potatoes	2800	Wastewater utilization association embracing the municipality and 440 farmers; cultivation of vegetables and fruits prohibited; irrigation ceases 3 weeks before harvest.
– United Kingdom	Greater London	Lagooned, digested sludge from sewage works	Field and horticultural crops	(3×10^6 t of sludge annually at 6–10% solids)	Metropolitan Public Health Division (Thames Water Authority) responsible for wastewater and sludge management.
Northern Africa and Western Asia					
– Tunisia	Tunis-Soukra	Wastewater (secondary effluent)	Citrus trees	600	Wastewater collection and treatment under responsibility of the national sanitation authority; Ministry of Agriculture responsible for distribution.
– Jordan	Zarga river/ King Talal Dam basin	River water consisting mainly of treated sewage	Trees, industrial crops, vegetables eaten cooked, vegetables eaten raw, depending on crop restriction	500	Various degrees of crop restrictions depending on distance downstream from effluent discharges (quota allocation system handled by Ministry of Agriculture; monitoring by Ministry of Health).

Table 1 (continued)

Continent/ country	Town or area	Waste used	Crops irrigated/produced	Approximate area irrigated (ha)	Organizational, institutional
Northern Africa and Western Asia (continued)					
– Kuwait	Country as a whole	Wastewater (tertiary treatment plant effluent)	Fruit trees, fodder crops, maize, wheat, vegetables (eaten raw or cooked); forestry	1000–2000 (estimated on basis of installed irrigation pump capacity)	Agricultural use is on enclosed farm complexes.
– Saudi Arabia	Riyadh-Dirab	Wastewater (tertiary treatment plant effluent)	Wheat, fodder crops	2500	Distribution by Ministry of Agriculture to individual farmers; flow metering at branch-off to farmer's plot; crop restrictions effective.
	Riyadh-Dariyah	Ditto	Date palms, lemon trees, fodder crops	800	
South-East Asia					
– China	Country as a whole	Excreta (untreated or stored or co-composted with animal manure and crop residues)	Reportedly, up to 70% of the excreta produced in rural areas and large quantities of urban night-soil are used as basic soil conditioner and fertilizer in agriculture. Application is usually by ploughing or harrowing into the soil prior to planting. Use is apparently not restricted to certain crops, and occurs both on individual farms and communally.		
– India	Country as a whole	Wastewater (untreated, diluted; partially treated)	Paddy rice, maize, wheat, sorghum, vegetables, fodder crops	> 70 000	E. g., Kanpur (U. P.): municipal corporation and farmers' association responsible for wastewater distribution; fees collected by corporation's operators.
	Calcutta	Wastewater ponds	Fish (carp species, tilapia, catfish)	3000	Ponds owned by landlords, Calcutta municipality and cooperatives; 4000 fishing families; seasonal fishing work force.
– Indonesia	Java Highlands	Excreta-fed domestic ponds	Fish (carp and tilapia) and water vegetables	21 000	Family-owned ponds (average size: 200 m^2); commercial sale of fish as well as consumption by owner families.

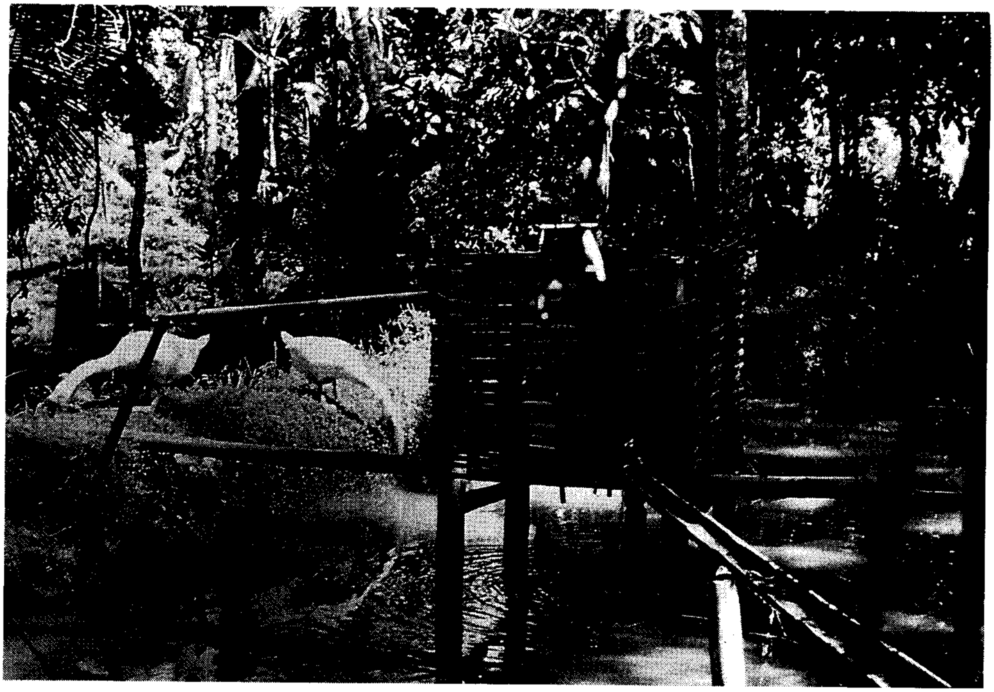


Plate 1. Near Bandung, Java, Indonesia: fish pond with overhanging latrine.
Photo U. J. Blumenthal

Wastewater is used notably in India, Latin America, Tunisia, the USA, and West Asia. Practices vary from the totally uncontrolled extraction of raw sewage from broken sewers to the use of well-treated wastewater in strictly administered schemes with restrictions on the crops to which it may be applied (Table 1).

An alternative waste management scheme has been developed in Guatemala, based on the decentralized, integrated and neighbourhood-controlled collection and recycling of solid and liquid wastes.

Traditional practices

In China the custom of storing organic human waste from rural and urban populations and using it in agriculture is still practised despite increased urbanization, industrialization and the use of chemical fertilizers.

Excreta collected in urban areas are transported to rural areas by truck, tractor, cart and boat. In 1981, of the 73 million tonnes of excreta and 73 million tonnes of solid waste produced in large towns, 40 million tonnes were used in agriculture, fish farming and aquatic vegetable production.

It has been estimated that of the 150 million tonnes of faecal waste produced annually by some 800 million people in rural China, 60–70% are recycled. The excreta usage rate amounts to at least 60–70%. Some 1.3 billion tonnes of animal manure were used in 1981. In some places excreta are stored for several weeks before use in order to destroy helminth eggs. Co-composting of human and animal excreta with crop residues is also practised, as is biogas production and the use of biogas slurry on the land. About 1.8 billion tonnes of organic fertilizer are produced annually by these processes. Its nutrient value is estimated to be equivalent to that of 100 million tonnes of inorganic fertilizer.

Most human and animal excreta, and excreta-derived compost, is generally ploughed or harrowed into the soil before crops are sown. The application rate for compost is usually in the range 100–300 tonnes/ha/year; that for liquid night-soil is generally 20–30 tonnes/ha/application. The exact rate is worked out with reference to: the quantity of available nutrients, especially nitrogen; the risk of inhibiting germination and growth; and the quantity that it is practicable to deposit on or incorporate into the soil.

In the hill areas of Java many villagers own small fish ponds into which human excreta from overhanging latrines (Plate 1) are allowed to fall *(3)*. Some farmers who produce fish on a large scale now use commercially produced, pelleted fish feed, but most farmers continue to use excreta as the cheapest and most readily available fertilizer.

The world's largest combined wastewater disposal and fish production system is in India (Plate 2). Wastewater and drainage water from East Calcutta are stored and treated in over 40 km^2 of lagoons where fish production has become a highly skilled operation *(4)*. Some 24 000 people are employed, full- or part-time, in this industry. The output provides 10–20% of the fish requirements of 10 million urban dwellers. The system destroys many pathogens, and there are probably few health risks associated with it. Treated wastewater from

Plate 2. Calcutta, India: the "Wetlands", wastewater-fed fish ponds.
Photo M. Strauss

the lagoons is used to irrigate 6000 ha of agricultural land, thereby providing a full or partial income for 3000 families. The system is an excellent example of ecologically and socioeconomically sound wastewater management.

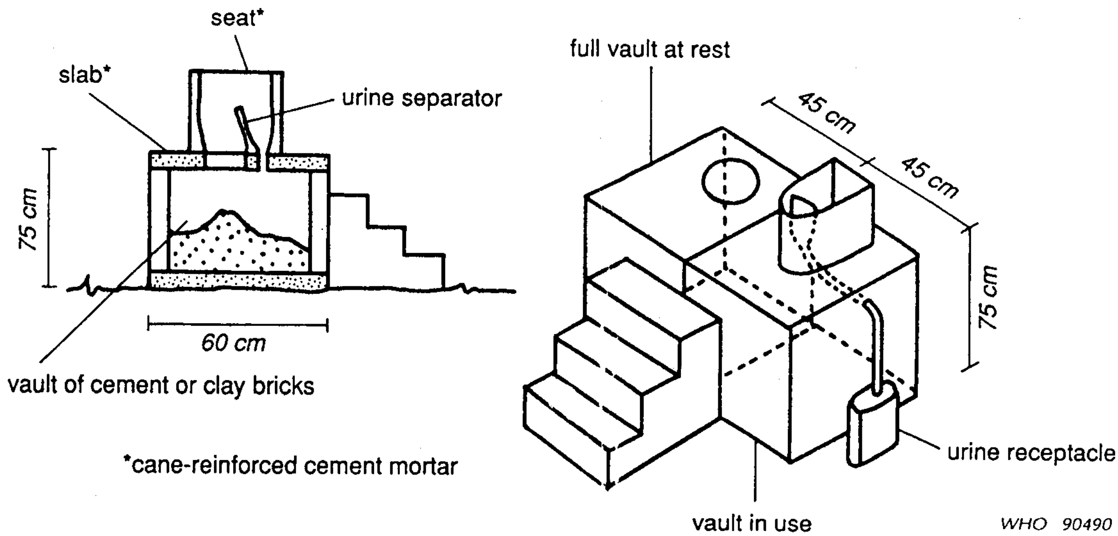
Wastewater is widely used on the outskirts of Mexico's urban areas, particularly in the arid and semi-arid zones *(3)*. Most of the wastewater and storm runoff from Mexico City is used to irrigate the Mezquital Valley, 60 km to the north. The wastewater is not treated but some destruction of pathogens occurs during passage through canals and reservoirs. The main crops are alfalfa, maize, beans, chillies and green tomatoes.

Soil conditioner/fertilizer from double-vault latrines

In Guatemala, the Centro de Estudios Mesoamericano sobre Tecnología Apropriada (CEMAT), collaborating with the local population, has developed and introduced a double-vault dry alkaline fertilizer latrine (Fig. 1) *(5)*. Each vault has an interior volume of about 400 litres. One vault is used at a time and when it becomes full the contents are left in place until the second is full. Filling takes five to seven months, depending on the number of users.

The design of the latrine permits people to defaecate in a seated position. Urine, collected separately by means of an internal funnel, is diluted and used to irrigate fruit trees and other plants. The water content of the faecal material in the vault is 45–50%. After defaecation, ash is put into the vault; this raises the pH above 9, helping to destroy pathogenic bacteria and viruses. The faecal material decomposes at ambient temperature in mixed aerobic and anaerobic conditions. After removal, the contents are stored in bags. This fertilizer, highly valued by subsistence farmers, is applied to the land by mulching, ploughing or "sandwiching", depending on the crop (Plate 3). The net-weight production, including ash, amounts to 70–80 kg/person/year. According to the users, the principal benefits derived from the latrines are, in order of priority, the production of organic fertilizer, their convenience, and improved hygiene. To date, some 4000 dry alkaline fertilizer

Fig. 1. Double-vault latrine with urine separation.



latrines have been constructed in Guatemala under the auspices of governmental and private organizations.

In a recent investigation it was found that the faecal product, which had been removed from latrine vaults after a minimum of 10 months and stored in bags at a mean ambient temperature of 18 °C and with a water content of 18%, contained an average of about 50 nonviable *Ascaris lumbricoides* eggs/g. Roundworm eggs, the most persistent pathogenic organisms, are a reliable indicator of hygienic quality.

Dry alkaline fertilizer latrines were recently introduced in a low-income neighbourhood on the outskirts of Mexico City, where families had lacked any kind of excreta disposal infrastructure. Lime is used instead of ash as people cook with gas or kerosene. The fertilizer can be sold for use in gardening and horticulture.

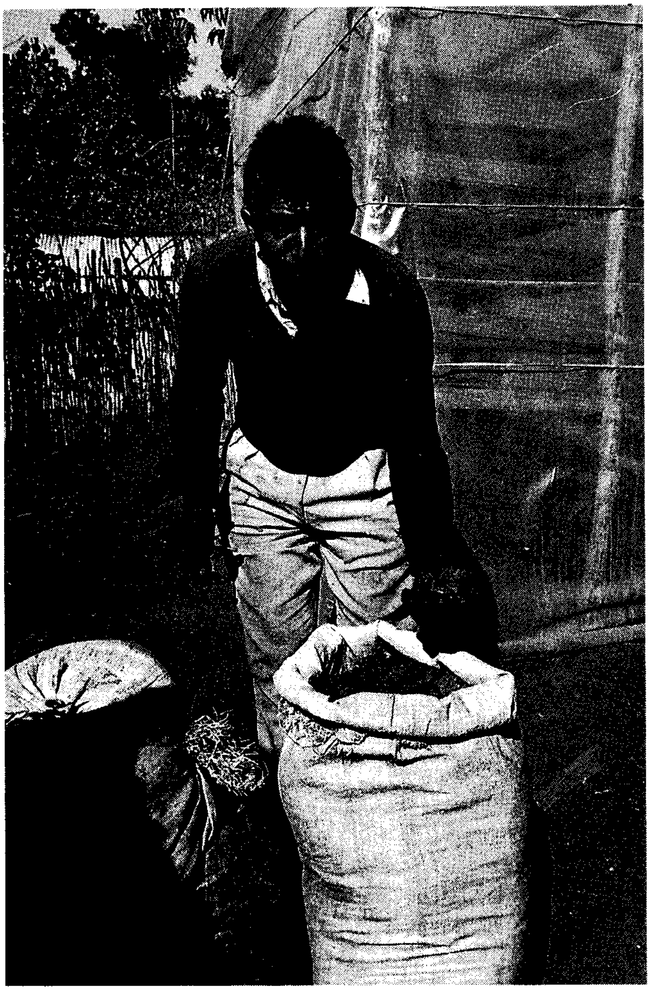


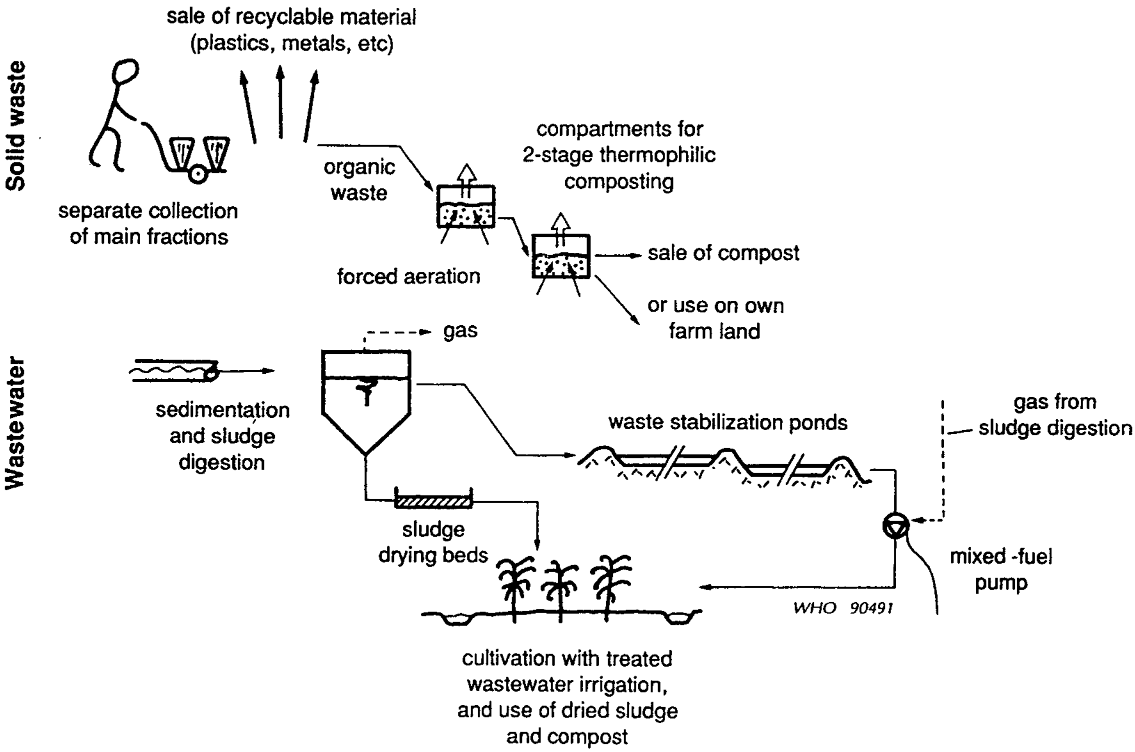
Plate 3. A Guatemalan farmer with a sack of fertilizer produced from human excreta.
Photo M. Strauss

Another type of double-vault latrine, made from polyester-reinforced fibreglass, has been developed in Mexico by the Grupo de Tecnología Apropiada, a nongovernmental organization that promotes appropriate technologies. The two vaults are watertight and used alternately; their bases are inclined and covered with small branches, wood chips and sawdust for the uptake of liquids. More wood chips are added during use. Both faeces and urine are disposed of in the vaults. To date, only a few prototype units have been introduced in Mexico City. No data are available on the hygienic quality and storage requirements of the decomposed faecal material removed from the vaults. The cost of the latrine is still too high for families on low incomes.

Integrated, decentralized and self-managed collection and recycling of wastewater and refuse

In urban areas of developing countries, adequate services for the

Fig. 2. Treatment and recycling of wastewater and refuse at Alameda Norte, Guatemala City.



disposal of excreta, wastewater and solid waste are often restricted to city centres and high-income localities, where technologies developed in industrialized countries are usually encountered, e.g., sewerage, use of vacuum tankers to empty septic tanks, and mechanized refuse collection. Public authorities very often disregard the waste-disposal needs of low-income areas because here the imported technologies are too sophisticated and costly.

In Latin America, many nongovernmental organizations strive to develop technologically and socioeconomically appropriate solutions to problems of excreta and refuse disposal as opposed to conventional ones. The alternative infrastructures tend to be community-based, i.e., planned, implemented and operated by the users.

The Alameda Norte waste-recycling plant in Guatemala City (Fig. 2) serves approximately 3000 persons in a low-income neighbourhood. The main fractions of solid waste are collected, following which manual separation of compostable and noncompostable material is necessary. Sieved compost is sold, as are plastic, metal and other fractions. Wastewater is treated in a settling and fermentation tank, where gas is produced. Further treatment in waste stabilization ponds is planned with a view to the removal of pathogenic organisms. The resulting effluent will be used to irrigate nearby fields, and the biogas produced will run the irrigation pumps.

Few operational data are yet available on the new system. It is not possible to say how the users cope with the many technical and managerial tasks. However, this technology represents an ecologically and socially sound alternative to the conventional centralized, government-administered disposal methods that have been developed in industrialized countries over the last century.

Hygiene

In developing countries where several types of enteric disease are prevalent there is a risk to public health from excreta that are not stored for an adequate period or effectively treated in some other way (Table 2).

Excreta and wastewater must be either stored long enough or treated adequately before use. The longest-surviving pathogens are worm eggs, particularly those of the roundworm *Ascaris*, which may remain viable for many months or even a few years. *Salmonella* may survive for a few months. Time and temperature are the two most important factors determining the duration of survival. Table 3 contains recommended storage periods for excreta at ambient temperatures in warm climates and indicates the various degrees of hygienic quality achieved.

Table 2. Some excreta-related infections

Type of organism	Example	Symptoms	Typical no./g faeces
Worms, worm eggs	*Ascaris* (roundworm)	Digestive problems, vomiting, constipation	10 000
Protozoa, protozoan cysts	*Amoeba*	Diarrhoea with blood and mucus; fever, chills	100 000
Bacteria	*Salmonella typhi*	Typhoid fever, constipation, nausea	100 000 000
Viruses	Rotavirus	Diarrhoea (mainly children)	100 000

Table 3. Recommended storage periods for excreta at ambient temperatures in warm climates

Storage period	Hygienic quality achieved
⩾2 days	Inactivation of *Clonorchis* and *Opisthorchis* (liver fluke) eggs
⩾1 month	Inactivation of viruses, protozoa, bacteria (except possibly *Salmonella* on moist, shaded soil) and schistosome eggs
⩾4 months	Inactivation of roundworm eggs, e.g., hookworm and whipworm (*Trichuris*); survival of some *Ascaris* eggs
⩾12 months	Complete inactivation of *Ascaris* eggs

Storage periods of several months to a few years are required at ambient temperatures, but treatment periods can be reduced proportionally to achieve hygienically safe products at higher temperatures. With thermophilic composting, for example, at temperatures of 60–70°C, safety can be achieved within a few weeks.

In tropical countries, the retention of wastewater in stabilization ponds is often the most feasible method of removing pathogens. The wastewater flows through several ponds in three to four weeks. Helminth eggs and protozoan cysts are removed by sedimentation, while bacteria and viruses die.

The following pond retention times are suggested in warm climates *(1, 6)*:

- For removal of helminth eggs and protozoan cysts: 15 days in a two-cell system or 11 days in a three-cell system.
- For removal of bacteria and viruses: 28 days in a three-cell system.

There is strong epidemiological evidence that the use of untreated/unstored excreta or wastewater can be associated with an actual risk of excess infection from intestinal nematodes, i.e., roundworm (*Ascaris*), whipworm (*Trichuris*) and hookworm

Institutions dealing with public health aspects of the use of excreta and wastewater

The following institutions are concerned with wastewater and excreta recycling, particularly as regards public health protection. The list covers bodies with which the International Reference Centre for Waste Disposal has collaborated on aspects of the use of human wastes.

Country	*Activities*
Latin America	
– CEMAT, Centro de Estudios Mesoamericano sobre Technología Apropiada Apartado Postal 1160 – Guatemala	Community development; latrine technology and microbiological aspects of dry fertilizer latrines
– CEPIS, Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente P.O. Box 4337, Lima 100 – Peru	Applied research and development in wastewater treatment and reuse
– SARH, Secretaria de Agricultura y Recursos Hidráulicos, Comisión del Plan Nacional Hidráulico Tepic 40, Mexico 7 DF – Mexico	Law-making, planning, monitoring and enforcement
– Instituto Mexicano de Tecnología del Agua Río Usuma Cinta No. 2 – Col. Vista Hermosa Cuernavaca – México	Planning, monitoring, research
North America	
– IDRC, International Development Research Centre – Health Sciences Division 60 Queen Street, P.O. Box 8500 Ottawa K1G 3H9 – Canada	Financing development projects
– US Environmental Protection Agency Waste Management Division 345 Cortland Street, N.E. Atlanta, Georgia 30365 – USA	Health effects monitoring; epidemiological aspects
– The World Bank Integrated Resource Recovery 1818 H Street, N.W. Washington, D.C. 20433 – USA	Applied research and development; financing infrastructure projects; technical assistance

Africa

– Ministère de la Santé publique, Département de l'Hygiène de l'Environnement Cité Welvert, Bab Saadoun, Tunis – Tunisia	Law-making, monitoring, enforcement

Asia

– AIT, Asian Institute of Technology Division of Agricultural & Food Engineering P.O. Box 2754, Bangkok 10501 – Thailand	Applied research and development of treatment and reuse options
– NEERI, National Environmental Research Institute – Wastewater Agriculture Division Nehru Marg, Nagpur 440 020 – India	Applied research and development in engineering and agronomic aspects of wastewater reuse
– Padjadjaran University Institute of Ecology Jalan Sekeloa, Bandung – Indonesia	Epidemiological aspects of excreta use in aquaculture

Europe

– University of Leeds Dept of Civil Engineering Leeds LS2 9JT – United Kingdom	Applied research and development in treatment and wastewater analysis for reuse
– London School of Hygiene and Tropical Medicine – Dept of Tropical Medicine Keppel Street London WC1E 7HT – United Kingdom	Research in epidemiological aspects of use of excreta and wastewater in agriculture and aquaculture
– University of Nancy – Faculté des Sciences pharmaceutiques et biologiques 5, rue Albert Lebrun F-54000 Nancy – France	Development of analytical methods for parasite detection in wastewater
– University of Newcastle upon Tyne Dept of Civil Engineering, Claremont Road Newcastle upon Tyne NE1 7RU United Kingdom	Research and technical assistance in planning and implementation of wastewater reuse
– World Health Organization Division of Environmental Health CH-1211 Geneva 27 – Switzerland	Sector guidelines and technical assistance

(*Ancylostoma, Necator*) (6, 8). The actual risk of excess infection by bacterial and viral diseases appears to be lower than for nematode infections. The epidemiological evidence for this is relatively weak, owing to a paucity of credible epidemiological investigations, but the the assumption is based on sound theoretical considerations of potential risk (typical transmission routes, pathogen die-off, and infective dose).

Agriculture

Human excreta can be used to restore and maintain good soil structure and fertility. They are as good a source of nitrogen, phosphorus and potassium as any other organic fertilizer or composted material. During storage or treatment much nitrogen is lost because of leaching and volatilization, a drawback also affecting other organic fertilizers.

Excreta are valued mainly for their soil-conditioning and humus-building potential. However, their nutrient content can be used to estimate a family's fertilizing potential, assuming a daily dry-weight excreta production of 110 g/person (Table 4) (7). A family of five adults can provide sufficient nitrogen and phosphorus to cultivate a rice plot ranging in area from 1600 m^2 to 2000 m^2. For maize, the area would be 20–30% smaller, while for soya beans it would be 25–50% larger.

In tropical countries the retention of wastewater in stabilization ponds is often the most feasible method of removing pathogens.

The evaluation and promotion programme for the dry alkaline fertilizer latrine in Guatemala comprised trials in which crops cultivated without any fertilizer were compared with others receiving organic fertilizer from such latrines and with ones receiving mineral fertilizers. As between organic and mineral fertilizer, the results were inconclusive for green peas, kidney beans, and radishes, but the organic fertilizer led to increased yields over untreated controls. For other crops the latrine fertilizer did not lead to a significant increase in yields. The application rates for the organic fertilizer were equivalent to 2500–3000 kg/ha/year of the material produced in the latrines.

Table 4. Fertilizer-producing potential of a family of five adults

	N	P_2O_5	K_2O
Nutrient content (% of dry weight)	8[a]	3.5	2.5
Daily per capita production (g)	8.8	3.8	2.7
Yearly production by five adults (kg)	16	6.9	4.9
Annual nutrient requirement for rice cultivation (kg/ha)[b]	98	34	80
Area of rice crop fertilized by a family of five adults (m^2)	1600	2000	600

[a] Assuming that 30–50% of the nitrogen contained in urine is lost as ammonia during anaerobic fermentation.
[b] Ministry of Foreign Affairs, France, 1984.

Fertilizer derived from excreta should be valued more for its humus-forming capacity than for the nutrients it provides. Although excreta-derived products contain nutrients in concentrations comparable to those of other organic manures, it should be borne in mind that organic products cannot compete on a unit weight basis with mineral fertilizers as suppliers of nutrients. Mineral fertilizers, however, have no humus-building capacity. Humus, the organic body of the soil, plays a decisive role in the adsorption, storage and regulation of nutrients and water, as well as influencing the aeration and temperature of the soil. □

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Food handlers need to know food safety rules

Food handlers often have little understanding of the risks of microbial or chemical contamination of food or how to avoid them. The job is frequently of low status and poorly paid, which leads to poor motivation. Rapid staff turnover also causes problems. Food handlers should therefore receive suitable training in the basic principles of food safety. Particular attention should be given to the importance of time and temperature control, personal hygiene, cross-contamination, sources of contamination and the factors determining the survival and growth of pathogenic organisms in food. The need to report illness immediately to the supervisor must be stressed.

At the end of the training period, the knowledge and understanding of food safety on the part of the food handler should be tested and it is suggested that a "health card" certifying an acceptable level of attainment should be issued to those who pass the test. Posters can be displayed in workplaces to remind food handlers of what they have learned.

— Adapted from *Health surveillance and management procedures for food-handling personnel.* Report of a WHO Consultation. Geneva, World Health Organization, 1989 (Technical Report Series, No 785), p. 25.