3
Examples of human wastes reuse

Wastewater irrigation schemes in Australia, the Federal Republic of Germany, India, Mexico and Tunisia are described in this section, as is the use of excreta or excreta-derived products in China, Guatemala, India and the United States of America. Descriptions of the aquacultural use of wastewater and excreta for fish culture in India and Indonesia are also given. There are many other examples of waste reuse (see Table 2.1, page 24); the selection given here was chosen to represent a wide range of geographical locations, sociocultural settings, scales of operation, treatment processes, application techniques and crops harvested.

3.1 Wastewater use in agriculture

3.1.1 Australia

Werribee Farm came into service as the principal sewage farm for the city of Melbourne in 1897, when the design population was 1 million. Today Werribee Farm receives an average flow of some 470 000 m^3/day of mixed domestic and industrial wastewater. This is treated either in waste stabilization ponds (1500 ha in area), or by land or grass filtration. Land filtration covers an area of nearly 4000 ha and treats a wastewater flow of some 195 000 m^3/day during the summer months of October–April. It is essentially the broad irrigation of pasture with raw wastewater. Irrigation is carried out on a three-weekly rotational basis: two days of wastewater application totalling 100 mm, followed by five days drying and then 2 weeks of grazing by livestock, mainly sheep and cattle. Some 10–11 applications of wastewater are made each season. Approximately half the wastewater is lost by evapotranspiration and seepage into the deep subsoil, and the remainder is collected by a series of effluent drains and eventually discharged into Port Philip Bay (Kirby, 1967). As a wastewater treatment process, it is very efficient: biochemical oxygen demand and suspended solids removal of 98% and 93% are achieved. During winter, land filtration is not feasible because of the lower rates of evapotranspiration, and grass filtration is practised instead. A flow of some 250 000 m^3/day of primary settled sewage is treated in an area of 1500 ha. At the end of the season cattle are admitted to feed on the pasture following seed-drop.

The farm carries a large number of livestock. There is a herd of some 13 000 adult cattle, which produce around 6500 calves each winter; most of these calves are fattened and sold at 18–22 months old. Only 0.02% of carcasses are condemned for contamination with *Cysticercus bovis* (beef tapeworm larva), which is a similar rate to that for cattle from other local farms; this demonstrates the effectiveness of the irrigation regime in preventing tapeworm transmission. In summer the farm has about 30 000 sheep; most of these are sold in the autumn, except for 6000 which are retained for winter grazing. These stockraising activities generate a gross annual income of some A$ 3 million (US$ 2.12 million) (Camp Scott Furphy Pty Ltd, 1986).

3.1.2 Federal Republic of Germany

Crop irrigation with treated wastewater has been practised at the city of Brunswick (Braunschweig; current population 325 000) in northern Federal Republic of Germany since 1971 (Kayser, 1985). Some 55 000 m^3/day of wastewater are treated in aerated lagoons and secondary sedimentation tanks, and 44 500 m^3/day (which includes 5100 m^3/day unthickened excess sludge and 5000 m^3/day raw wastewater from villages near the irrigation fields) are used to irrigate 2800 ha of farmland. The irrigation scheme is operated and managed by the Brunswick Wastewater Utilization Association (BWUA), whose members are the city of Brunswick and the 440 individual farmers who own the land. The irrigation area is divided into four irrigation districts, each with its own pumping station and wastewater balancing tank. The wastewater is distributed by subsurface asbestos cement pressure pipes (100–500 mm diameter), and subsurface hydrants are located 90 m apart. Wastewater is applied to the crops by means of sprinklers (20 mm nozzle diameter) attached to drum-coiled irrigation machines. During normal operation the sprinkler takes 20 hours to apply 50 mm of wastewater at a pressure of 4 bars (400 kPa) to a strip of land measuring 300 m × 50 m. Usually 50–60 machines are in operation, although this may rise to 100 in summer when ground water is also used for irrigation;

six heavy-duty tractors are used to position the machines and pull out the 300 m sprinkler pipe over the field. Each tractor is manned by a crew of two in summer and one in winter when low pressure irrigation is practised essentially as a wastewater disposal technique.

The annual wastewater application rate is 580 mm, and the applied nutrient loads (kg/ha per year) are: nitrogen 379, phosphorus 106 and potassium 105. The light, very permeable soil requires liming to maintain the pH, and supplementary potassium and nitrogen fertilizers are used. The principal crops grown are winter and summer grain, sugar-beet and potatoes. Yields are similar to those from fields irrigated with ground water and artificially fertilized.

Only a small fraction of the total wastewater applied to the fields is collected in tile drains and discharged to a local river; most is either evaporated or flows into the ground water. Final effluent quality is high (<1 mg BOD per litre), although the nitrate concentration of 25 mg nitrogen/litre is giving rise to serious concern. No problems have been encountered with heavy metal accumulation in the soil.

Health risks are minimized by prohibiting the growth of vegetables and fruits in the irrigation area, and by a BWUA irrigation decree to eliminate the spread of pathogens from the sprinklers. This decree stipulates that 10-m wide hedges have to be planted along borders with public roads and that irrigation should not take place within 50 m of public roads and 100 m of houses. Special low-level sprinklers have to be used within 115 m of roads and houses, and sprinkler operation closer than 100 m to roads is permitted only when the wind direction is from the road to the field. Irrigation is ceased three weeks before crops are harvested. Investigations have indicated that these measures are sufficient to control disease transmission.

The BWUA irrigation scheme is strictly managed. An irrigation schedule is worked out every year in winter according to the farmers' cultivation plans. In summer, depending on the actual weather conditions, the schedule is refined each week. BWUA staff are responsible for operating the whole irrigation system, maintaining the pumping stations, moving the irrigation machines and for general maintenance and repair. In addition two employees act as internal controllers to ensure that the irrigation decree is rigidly observed.

Energy consumption is high, approximately 0.5 kWh per cubic metre of wastewater treated and irrigated, or some 8 million kWh per year. Operating costs are correspondingly high, amounting to nearly DM 8 million (US$ 4 million) per year, of which the farmers pay 5% at a rate of DM 120 (US$ 60) per hectare of irrigated land. The city of Brunswick pays the remainder, and justifies this cost on the basis that the scheme serves as an effective sludge disposal system, as well as an advanced tertiary wastewater treatment system.

3.1.3 India

A recent report prepared for the Food and Agriculture Organization of the United Nations (Shende, 1985) indicates that there are over 200 wastewater irrigation schemes currently in operation in India, covering an area of approximately 73 000 ha. Many of these schemes, however, are operated "in a crude and irrational manner" and with substantial actual health risks since most of the wastewater used for irrigation is untreated (see Section 4.3). Excessive wastewater application rates are used (up to 12 m per year), resulting in very high nutrient loading rates (up to 600 kg total nitrogen per hectare per year), because most schemes are operated more for wastewater disposal than for optimal resource recovery. Information on 13 major schemes is given in Table 3.1. Irrigation is by surface application methods, ranging from uncontrolled flooding to fairly well managed ridge and furrow, border strip and check basin irrigation. Subsurface and sprinkler irrigation are not practised on sewage farms in India.

Despite this generally discouraging picture of the current status of wastewater irrigation in India, there are some noteworthy successes. Experience gained by the National Environmental Engineering Research Institute (NEERI) from long-term field studies indicates that:

- Grain yields are significantly improved by wastewater irrigation compared with irrigation with fresh water alone, even when raw wastewater is diluted with two volumes of fresh water. Yields can be increased further by adding supplementary NPK fertilizer up to the recommended dose.

- Vegetable yields are also much higher when wastewater irrigation is practised instead of traditional manuring and freshwater irrigation (see Table 3.2).

Table 3.1 Details of thirteen sewage farms in India

Location	Area (ha)	Volume of sewage used (mld)[a]	Treatment, if any	Dilution if any	Application rates (m^3/day/ha)	Soil type	Crops grown
Ahmedabad	890.3	299.9	Nil	Nil	336.8	Sandy loam	Pochia grass, paddy, maize, jowar, wheat, lucerne
Amritsar	1214.1	54.5	Nil	1:3	44.9	Sandy clay	Maize, berseem, sorghum, lucerne
Bikaner	40.4	13.6	Nil	Nil	336.8	Sandy	Bajra, wheat, grasses, vegetables
Bhilai	607	36.3	Secondary (stablization pond)	Nil	59.9	Sandy loam, clay loam	Paddy, maize, wheat, tuwar, vegetables
Delhi	1214.1	227.2	Primary and secondary	Nil	187.1	Sandy loam, loamy sand	Jowar, bajra, maize, barley, wheat, pulses, vegetables
Gwalior	202.3	11.3	Nil	Nil	56.1	Silt loam, clay loam	Paddy, maize andguar, jowar, cowpea, wheat, potato, berseem, vegetables
Hyderabad	607	95.4	Primary	1:1.5	157.2	Loam	Para-grass, paddy
Jamshedpur	113.3	9.1	Secondary activated sludge	Nil	80.2	Clay loam	Napier grass, para-grass, guinea grass, berseem, jowar, maize
Kanpur	1416.5	31.8	Nil	1:1	22.4	Loam, silt loam	Wheat, paddy, maize, barley, potato, oats, vegetables
Madras	133.5	6.8	Nil	Nil	51.0	Sandy to silt loam	Para-grass.
Madurai	76.9	136	Nil	Nil	177.3	Red sandy loam	Guinea grass
Trivandrum	37.2	8.6	Nil	1:1	231.9	Sand	Para-grass
Lucknow	150	300	Nil	1:3	–	Sandy loam	Maize, paddy, potato, vegetables, fruits, papaya, plantains, citrus

[a] Million litres per day

Reproduced by permission from Shende (1985).

Table 3.2 Yields of crops irrigated with canal water and diluted and undiluted wastewater at Poona sewage farm

Crop	Annual crop yield (t/ha)		
	Canal water[a]	Diluted wastewater[b]	Undiluted wastewater
Beetroot	8.75	15.60	16.27
Carrot	9.71	8.72	11.75
Radish	7.26	6.14	8.33
Turmeric	–	20.64	21.59
Potato	6.12	7.00	9.33
Ginger	6.04	9.18	9.80
Papaya	26.72	27.91	37.00
Kholkhol	9.70	11.76	16.57
Cabbage	9.27	11.32	12.13
Cauliflower	6.96	7.08	9.09
Okra	2.82	3.60	5.89
French beans	6.63	8.20	8.06
Tomato	10.01	–	13.38
Tobacco	1.12	1.25	1.25
Groundnut	2.88	2.90	3.17
Sugar (cane)	–	52.75	54.43
Sugar (jaggery)	–	5.67	5.78

[a] Land manured before planting
[b] 1 : 1 dilution

Reproduced by permission from Shende (1985).

- Irrigation with wastewater results in a higher nutrient utilization efficiency, and permits higher yields to be maintained in the long term (see Box 2.1, page 27).

- Irrigation of trees with raw wastewater results in yields similar to those obtained from freshwater irrigation—approximately 55 tonnes of marketable eucalyptus timber per hectare after 24 months, with a market value of Rs 27 700 (US$ 2170).

- The effect of wastewater irrigation on soil properties depends strongly on the original soil characteristics, but in many cases—even after 30 years of wastewater irrigation— soil productivity remains highly favourable.

3.1.4 Mexico

Agricultural development in Mexico is highly dependent on irrigation: 77% of the land is arid or semi-arid and the mean annual rainfall for the whole country is only 760 mm, occurring mainly between July and September. Wastewater use in agriculture is practised throughout the country in almost every city that has a sewerage system. In some irrigation districts a blend of wastewater and fresh water is used, but in Rural Development District No. 063 in the Mezquital Valley, State of Hidalgo, almost all the water used for irrigation is the wastewater from Mexico City and its metropolitan area, which has a total population of 18 million. The wastewater is used for crop irrigation in two Irrigation Districts (Nos 03 and 100); these comprise a total of 85 000 ha of irrigable land, of which 80 000 ha are currently irrigated. The principal crops grown are alfalfa, maize, wheat, oats, beans, tomatoes, chillies and beetroot. The combined wastewater and storm water flow of 55 m^3/s, of which 30–45 m^3/s is raw wastewater, makes the Mexico City wastewater use scheme the largest in the world (Villalobos et al., 1981; Duron, 1985; Strauss, 1986a; Romero-Alvarez, personal communication, 1987).

The combined wastewater and storm water from Mexico City flows in three large canals to the Tula basin which lies to the north of the city. This area, which is some 2000 m above sea level and has an average temperature of 17 °C, is semi-arid: annual rainfall averages 483 mm and evaporation 810 mm. Irrigation is thus essential for successful agriculture. No treatment *per se* is given to the wastewater, but a certain degree of treatment occurs naturally during its 60 km journey from Mexico City to Tula. Further treatment takes place in storage reservoirs which are used to regulate the flow to the irrigation canals. Some of these storage reservoirs also impound local rivers, thus diluting the wastewater.

In Irrigation District No. 03, within the Tula basin, there are approximately 200 km of main irrigation canals and 350 km of lateral channels covering an area of 43 000 ha. Irrigation water usage, much of which is regulated by several reservoirs, amounts to $1–1.4 \times 10^9$ m^3 per year. Data on irrigation water quality are scanty, but there have been no serious problems with salinity, sodicity or heavy metals over the past 30 years, despite the generally low quality of the irrigation water. This is attributed to the good internal drainage and high calcium content of the local soils which have prevented the accumulation of dissolved salts and exchangeable sodium. The crops grown are tolerant to the relatively high levels of boron present in the irrigation waters, but some crops irrigated with wastewater (for example alfalfa) have shown higher concentrations of heavy metals (cadmium, chromium, selenium and zinc) than those irrigated with fresh water. No detailed information on bacteriological quality is available, but some samples have contained between 10^3 and 10^8 faecal coliforms per 100 ml.

The Irrigation District produces a considerable quantity of food, mainly for the markets of Mexico City and local consumption (see Figure 3.1). In addition to the main crops shown in Table 3.3, vegetables are grown on some 400 ha; there is enforced crop restriction, and those that cannot be grown include lettuce, cabbage, beetroot, coriander, radish, carrot, spinach and parsley. The District's canal and gate operators, who are in close contact with the farmers, are responsible for ensuring that these crops are not grown. There is also a small, but valuable, production of fruit and flowers. Research into oil-bearing crops (sunflower, safflower and rape) is in progress.

Administratively the Irrigation Districts, which were established in their present form by presidential decree in 1955, are controlled by a committee composed of representatives of central government (the Secretariat of Agriculture and Water Resources, SARH), the farmers and local credit banks. The responsibilities of the District comprise:

- construction, operation and maintenance of the irrigation and drainage canals;
- maintenance of access roads;
- allocation of irrigation water to farmers;
- administration of farmers' crop-growing schedules;
- enforcement of prohibited crop ordinances; and
- provision of an agricultural extension service to the farmers.

The Irrigation Districts Nos. 03 and 100 are divided into several administrative areas. Farmers place their water demands with their local District office, specifying where and when the water is required. The farmers, who are either individual

Figure 3.1 A farm in Mexico's Irrigation District 03, irrigated with untreated wastewater from Mexico City

The small boy is not wearing shoes, and is therefore exposed to hookworm infection because of the flood irrigation method in use

Table 3.3 Yields of principal crops and areas harvested in Irrigation District No. 03, Mezquital Valley, Mexico

Crop		Area harvested (ha) and yield (kg/ha)			
		1970–71	1975–76	1980–81	1985–86
Maize	Harvested (ha)	17 914	21 023	17 907	19 539
	Yield (kg/ha)	3 938	3 896	4 566	4 600
Beans	Harvested (ha)	1 266	1 222	1 646	1 501
	Yield (kg/ha)	1 259	1 768	1 521	1 800
Wheat	Harvested (ha)	7 293	2 634	2 005	167
	Yield (kg/ha)	1 919	3 119	3 225	2 900
Alfalfa	Harvested (ha)	12 708	15 206	20 339	20 630
	Yield (kg/ha)	95 300	89 154	91 175	81 200
Oats	Harvested (ha)	2 998	691	1 002	1 592
	Yield (kg/ha)	18 150	19 898	32 470	23 600
Barley	Harvested (ha)	–	832	1 812	1 514
	Yield (kg/ha)	–	19 620	19 939	15 500
Pastures	Harvested (ha)	13	11	65	30
	Yield (kg/ha)	142 500	107 000	44 276	89 100

Source: Duron (1985) and Secretariat of Agriculture and Water Resources (personal communication).

smallholders or work in cooperatives, pay a water fee of 40 pesos (US$ 0.12) per hectare per irrigation cycle (approximately 20 pesos (US$ 0.06) per 1000 m^3), which is insufficient to permit full cost recovery — subsidies are received from the State. Farmers irrigate every 25–30 days.

The success of the Mexico City wastewater use scheme has been dependent upon a number of factors, including:

- the suitability of the local soils for wastewater irrigation;
- the highly increased soil productivity resulting from wastewater irrigation, which makes it possible to grow more than one crop per year;
- the availability of large tracts of originally semi-arid land;
- a highly developed and well maintained wastewater distribution system;

- enhanced security for the local farmers, who do not have to rely on rain-fed agriculture but have the use of steadily increasing amounts of wastewater;
- sound management of the wastewater irrigation districts, which have over 80 years of experience of wastewater irrigation; and
- the absence of any demonstrated risk of the transmission of excreta-related disease.

3.1.5 Tunisia

Tunisia is a highly agricultural country; of its total land area of 160 000 km^2, some 90 000 km^2 are cultivated, and 50% of the country's 7 million people live in rural areas. The main products are wheat, barley, citrus fruits, olives, dates and wine, and the value of agricultural exports is high. Little rainfall occurs in the summer, and irrigated agriculture is well developed. Wastewater use is becoming increasingly common, as alternative water sources (impoundments, ground water) become insufficient in quantity and quality. To avoid over-pumping ground water, a major use has been found for wastewater in preventing the intrusion of salt water into coastal aquifers. Currently there are twelve reuse schemes, with three more being implemented and plans for a further five (Strauss, 1986b). Most of the wastewater used for irrigation is secondary effluent but some sewage treatment plant sludge is also being utilized. A wide variety of crops is cultivated—citrus and other fruit trees (Figure 3.2), fodder crops, and vegetables. In one tourist location, a golf course is watered with activated sludge effluent.

Wastewater from the capital city of Tunis has been reused for the irrigation of citrus trees since 1964. Some 600 ha of land are irrigated in the neighbouring district of Soukra, and there are new schemes under implementation that will expand wastewater use to about 5000 ha in three principal irrigation districts around Tunis in the near future. The effluents from four treatment plants (two activated sludge, one waste stabilization pond complex and one oxidation ditch), totalling some 250 000 m^3/day, will be used. The waste stabilization ponds, at Côtière Nord, comprise two parallel series of three ponds (the first of which is mechanically aerated) which discharge into a common quaternary pond. The overall retention time is currently 180 days, and, at the maximum design flow, 58 days; the bacteriological quality of the effluent is certainly well

Figure 3.2 A citrus orchard in Tunisia, irrigated with treated wastewater
Buried pipes distribute the water and riser ("bubbler") pipes apply it to the depression formed around each tree

within the microbiological guidelines recommended by a WHO Scientific Group for wastewater reuse in agriculture.

Wastewater is distributed to farmers by local Agricultural Development Authorities, which are responsible to the Ministry of Agriculture. These Authorities construct and maintain the wastewater distribution system (pipelines, pumping stations, storage reservoirs, etc.), distribute the wastewater to the farmers according to an organized delivery schedule, and collect revenue. The farmers are responsible for on-farm distribution of the wastewater and pay 0.025 dinars (US$ 0.031) per m^3 of wastewater to the Authorities by quarterly bills. The Authorities forbid the irrigation of crops eaten raw and have legal powers to enforce this restriction. Their personnel maintain regular contact with the farmers and ensure that the system is working properly.

3.2 Excreta use in agriculture

3.2.1 China

In China natural organic wastes are extensively used for soil fertilization. These wastes include excreta, domestic refuse, animal manure (principally from pigs and cows), crop residues and green manures such as *Azolla* and other aquatic plants. Urban nightsoil is collected and transported by cart, tractor and boat to rural areas. In 1981, 73 million tonnes of nightsoil and 73 million tonnes of refuse were produced in large- and medium-sized cities; of this, some 40 million tonnes were reused in agriculture and aquaculture. Treatment, although now becoming more common, is comparatively rare, with less than 5% of reused wastes being treated; composting is the most usual treatment process. Urban wastes that are not directly used in agriculture are generally disposed of in sanitary landfills which, when complete, are most commonly used for agricultural production (Zhongjie, 1986).

In the rural areas of China the wastes from some 800 million people are reused: the excreta usage rate is over 70% (Zhongjie, 1986). Animal manure is widely used—about 1.3 billion tons in 1981, as compared with 150 million tons of human excreta. Excreta are generally stored for four weeks before use, in order to destroy helminth eggs. Co-composting of human and animal excreta with crop residues is widely practised, as is biogas production, with subsequent use of the biogas slurry on the land. Nearly 2 billion tons of organic fertilizer are produced annually by these processes. Artificial fertilizers are used, but reliance on waste-derived organic fertilizers will continue because (FAO, 1977):

- there is 4000 years' experience of matching the various types of organic fertilizers to the local soils, and it will take time to develop an equivalent understanding of artificial fertilizers;

- artificial fertilizers are relatively expensive, whereas organic fertilizers are widely available at little or no financial cost;

- farmers generally prefer organic fertilizers because they increase the humus content of the soil and so improve its structure and water retention;

- Chinese soils are generally more responsive to nitrogen than to phosphate, and to phosphate than to potassium; most soils are not deficient in micronutrients because of the long-term application of organic fertilizers; and

- the construction of artificial fertilizer factories is very expensive, and the development of a fertilizer industry has to be a gradual process, depending upon the availability of internal resources rather than upon imports.

The bulk of human and animal excreta and excreta-derived compost is generally applied during land preparation before planting, and is ploughed or harrowed into the soil. The rate of application varies according to the soil, crop and season, but application rates for composts are usually 100–300 t/ha per year, and for liquid nightsoil 20–30 t/ha at each application. The principal criteria used to determine the exact application rate in any one case are: the quantity of available nutrients, especially nitrogen; prevention of any inhibition of germination and seedling growth; and the amount that can be effectively deposited on or incorporated into the land.

Experiments have shown that even relatively low application rates (15–40 t/ha per year) of excreta-derived compost can substantially increase crop yields (FAO, 1977): maize, 29%; millet, 48%; potato, 89%; sorghum, 85%; soya bean, 23%; sugar-beet, 26%; wheat, 39%.

3.2.2 Guatemala

Following the 1976 earthquake, the Centro Mesoamericano de Estudios sobre Tecnologia Apropriada (CEMAT) has been developing simple rural sanitation technologies that are compatible with agricultural reuse. A modification of the Vietnamese double-vault composting toilet, known as the Dry Alkaline Fertilizer Family (DAFF) latrine (or Letrina Abonera Seca Familiar, LASF), has been developed and is now fairly well established in some parts of rural Guatemala (Cacares, 1981; Strauss, 1986a). The DAFF latrine is an above-ground facility, comprising two alternating vaults constructed in brickwork and a simple bamboo superstructure. Faeces only are deposited in the vaults, and urine is collected separately. Ash from wood-burning stoves is added to the vault at least daily and preferably after each use. When one vault is full (usually after 4–6 months), it is sealed and the other vault is put into service. When the second vault is full, the first is emptied (see Figure 3.3) and its contents kept for application to the land immediately before planting or sowing. Urine, after dilution with water, is used for plant watering.

After 4–6 months of anaerobic mesophilic composting in the vault the contents are transformed into a dry, odourless material with a crumbly soil-like consistency. The organic matter content is 3–10%

Figure 3.3 A DAFF latrine in Guatemala being emptied
The digested excreta is then applied to the land

with 0.3–1.1% total nitrogen, 150–410 mg/kg of total phosphorus and 7000–7600 mg/kg of total potassium; the pH is high because of the large quantities of ash added and in the range 9.8–11.2. Coliform counts are reasonably low, generally less than 4000 per gram (wet weight), and helminth eggs are fewer than 8500 per gram with a viability of less than 30%. This microbiological quality is considered safe for reuse (Zandstra, 1986).

Local farmers regard the DAFF latrine as useful because:

- it provides a readily available, low-cost fertilizer and soil conditioner which "noticeably" improves crop yields (quantitative yield data are not available); and

- it is an odourless household sanitation facility that avoids the need for indiscriminate defecation in the fields.

Occasionally insufficient quantities of ash are available and sometimes soil or lime is added instead of, or in addition to, the ash in order to keep the vault contents at a moisture content of around 50%.

The DAFF latrine costs about US$ 70 to construct, and there is an additional cost of US$ 70 per latrine to cover training and promotion. The compost produced is worth US$ 12 per 50-kg bag and, as a family of five can produce 10 bags annually, the latrine costs can be recovered in little over a year.

3.2.3 India

Agricultural use of nightsoil is common in India, especially in areas near towns and cities (Strauss, 1986d). Nightsoil from bucket latrines is taken manually to transfer stations, from where it is transported by cart or truck to trenching grounds or delivered directly to the farmers. The nightsoil is sometimes stored in pits before use, but much is used without any treatment. Some is applied to the field before planting, and in other cases it is applied while the crops are growing. In some cities, such as Greater Calcutta, Kanpur and Lucknow, nightsoil and municipal refuse are co-composted. In the Calcutta region the compost is sold to farmers at an average rate of Rs 2.50 (US$ 0.23) per tonne; demand for the compost is often high, and it is frequently sold before it is fully matured. Strauss (1986d) gives the following quotation describing the nightsoil trenching and composting operations in Greater Calcutta:

> In the majority of cases the trenching or composting ground is not well suited for the purpose. Either they are low lying areas subject to flooding

in the monsoon, or the land is inadequate being mostly filled up, or inhabitation has come up all round or there is no approach to the ground. Neither composting, nor trenching is practised in a scientific way. Generally the nightsoil is emptied into pits of any size and no coverage by ash or mud is given. Once filled they are fully exposed to fly breeding etc. In some cases they even look like cesspools being filled with water during the rains. Similarly, composting also is not practised in a scientific way. Refuse and nightsoil are simply dumped in any fashion and in any proportion. In some municipalities it was even observed that nightsoil is emptied into water bodies within the trenching ground and this water is being used for bathing and washing etc. Workers are generally immunised but no other protection is provided to them. Municipal workers involved in the operation of disposal grounds are mostly ignorant about the technicalities involved.

In many of the excreta use schemes in India there is little apparent control, and the actual health risks are probably high (see Section 4.3). The current programmes for the replacement of bucket latrines with twin-pit pour-flush toilets will mean a gradual reduction in the quantity of fresh nightsoil available for agricultural use and a concurrent increase in the quantity of safe latrine sludge.

3.2.4 United States of America

The city of Kearney, Nebraska, has a population of 25 000 and produces some 3000–4000 tonnes of sludge annually at its wastewater treatment plant (Anon., 1986). Before 1984, this sludge was dewatered to 20% solids and transported 25 km for landfill disposal at an abandoned airbase. Now it is taken just 0.4 km to a local farm for co-composting with feedlot manure. The sludge and manure are mixed in the proportion 1:2, composted in mechanically turned windrows for five weeks, and stockpiled for four to five months. The compost is then spread on 1200 ha of agricultural land (used for raising corn) twice a year in spring and autumn, at the rate of 7.5–10 t/ha. It contains sufficient phosphorus and potassium, but the sandy soil requires the addition of supplemental nitrogen. The retail value of the nutrients in the compost is high: some $28 per tonne (see Table 3.4). The water retention of the soil is better because of its increased humus content, and no artificial fertilizers (other than the supplemental nitrogen) are required. Although this case study describes only a small-scale operation, its potential for replication in an intensely agricultural state is clearly very high.

Table 3.4 Retail value of nutrients in composted sludge and feedlot manure at Kearney, Nebraska

Nutrient	Concentration in compost (kg/t)	Cost (US¢/kg)	Value (US$/t compost)
Nitrogen	6.4	59.4	3.80
Phosphorus	7.3	66.0	4.82
Potassium	30.9	33.0	10.20
Sulfur	2.3	50.6	1.16
Zinc	0.1	330.0	0.33
Calcium	11.8	1.8	0.21
Magnesium	3.2	5.5	0.18
Iron	1.8	330.0	5.94
Manganese	0.1	163.0	0.16
Copper	0.2	748.0	1.50
		Total value: US$	28.30

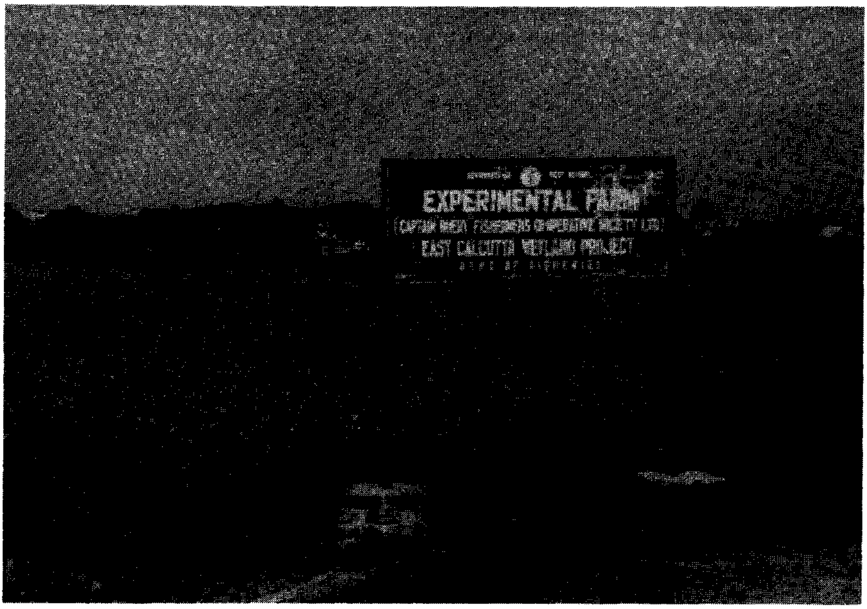
3.3 Wastewater and excreta use in aquaculture

3.3.1 India

There are more than 132 wastewater-fertilized fish-pond systems in India, covering an area of 120 km^2; most are located in West Bengal. The largest of these is the Calcutta wastewater fisheries, and this system is also the largest example of wastewater-based aquaculture in the world (Bose, 1944; Edwards, 1985; Strauss, 1986d).

Raw wastewater from Calcutta is conveyed in two 27-km canals to the North and South Salt Lake fisheries constructed on the wetlands of East Calcutta. The canals feed into a complex system of secondary and tertiary canals, from which wastewater is fed into the fish-ponds (see Figure 3.4). There are some 4400 ha of ponds, which are stocked with Indian major carp and tilapia. The ponds are emptied each year in February to remove the bottom mud and any vegetation, and refilled with partially diluted wastewater 6 to 8 weeks later. After a period of 2–3 weeks to permit the development of phytoplankton, the ponds are stocked with fish and wastewater is slowly fed into them for 5–10 days each month; this slow rate of wastewater introduction avoids deoxygenation of the fish-ponds. The fish attain marketable size in 5–6 months, and mean annual yields for the North and South fisheries are approximately 1400 and 1000 kg/ha respectively.

Figure 3.4 Wastewater-fed fish farming in Calcutta, India
This experimental pond is part of a vast system to the east of the city



Some of the fish-ponds are leased from the City of Calcutta, some are privately owned and a few are run as cooperatives; they provide employment for the local people at a rate of 7.5 persons per hectare. The fish are caught at dawn in traditional drag nets and sold at local auctions, from where they go to the Calcutta markets; by 0700 h most of the day's catch has been sold. The fish-ponds supply 10–20% of the fish consumed in Greater Calcutta.

Trematode infections are not endemic in West Bengal, and total coliform counts in the fish-ponds are around 100–1000 per 100 ml. This, together with the fact that the fish are consumed well cooked (usually by deep frying), indicates a low potential risk for disease transmission.

3.3.2 Indonesia

The fertilization of fish-ponds with excreta is mainly practised in southeastern West Java. In the four regencies (administrative areas) of Bandung, Ciamis, Garut and Tasikmalaya, where this practice is most common and which have a population of nearly 8 million, some 33 000 tonnes of fish, predominantly common carp and Java and Nile

Figure 3.5 An overhanging latrine in Java, Indonesia
Excreta fall into the pond and fertilize fish production. The bamboo pipes in the foreground bring water for bathing and washing from other ponds

tilapia, are produced annually in approximately 10 000 ha of ponds (B. Abisudjak, personal communication).

Strauss (1986c) describes excreta-based fish culture in the village of Cikoneng, which has a population of 3900 and is located 20 km south-east of Bandung. Cikoneng is a typical "pond village": the natural surface drainage from rivulets and streams discharges into 5 ha of ponds (the average pond size is 590 m^2), into which local run-off and water from paddy fields are also directed through bamboo gutters and pipes. The ponds are interconnected, and water flows from the upper to the lower ponds. The ponds are used for washing and bathing by all except the richer families who have their own well, and overhanging latrines (Figure 3.5) are constructed in the ponds for excreta disposal and direct fertilization of the fish. Rice bran and chicken manure are also used by some families for fertilization. The ponds are completely drained once a year, and all the fish are caught and sold. Annual fish yields are in the range 1600–2800 kg/ha. The bottom mud is removed and used in the local rice fields as a soil conditioner and fertilizer. Fish are also caught once a week for local consumption after cooking. In some ponds, water spinach is also grown, and this is eaten as a cooked vegetable. Diarrhoeal disease is not a major health problem in the village, with around only one episode per person per year. Faecal coliform counts in the fish ponds range between 10^4 and 10^5 per 100 ml. Trematode infections (clonorchiasis, fasciolopsiasis and schistosomiasis) are absent. The practice of fish-pond fertilization with raw excreta does not appear to promote any significant excess transmission of excreta-related disease.