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14

Health Aspects of Waste Re-use

14.1 INTRODUCTION

Human wastes are a valuable natural resource and should not be thrown away (Figure 14.1). Re-use of sewage, nightsoil, organic refuse and sludge derived from sewage treatment processes is possible in most situations. As discussed in Chapter 8, there are three main forms of re-use: agriculture, aquaculture and biogas. There are no specific health risks associated with biogas production other than those due to the handling of excreta which apply to many sanitation systems. We will therefore discuss only those health risks related to agriculture and aquaculture.

Human wastes from all communities contain pathogens (Table 1.3). These pathogens survive to different degrees as the waste is transported, treated and applied to the land or pond. The health risk associated with waste re-use depends on the degree of treatment which has been provided and the nature of the re-use process. A detailed account of this subject is provided by Mara and Cairncross (1989).

14.2 HEALTH AND AGRICULTURAL RE-USE

Sewage and nightsoil are often used in agriculture, sometimes in an organized way but often informally, illegally or clandestinely. In arid areas, such as coastal Peru and the middle East, sewage is at a premium because water is scarce, and in densely populated parts of the world, such as China and India, excreta are valued as a fertilizer.

The river water used for irrigation in many developing countries, and also in Europe and North America, often contains a substantial percentage of municipal sewage. This can also be considered an indirect form of re-use.

Many re-use schemes are found in industrialized countries. For example, the Werribee farm irrigated with treated sewage from the

The Good Daughter-in-law
by Hsieh Chang-yi

"Early in the morning, the magpies cry,
The newly-wed daughter-in-law is carrying excreta on a pole
Liquid from the excreta stains her new trousers
The hot sweat soaks into her embroidered jacket
The commune members praise her and mother is pleased
All tell her she has got a good daughter-in-law."

Figure 14.1 In some countries, such as China, the use of human excreta in agriculture is an ancient practice and may provide the main source of fertilizer for the fields. In other countries, such as much of Africa, it is considered much less acceptable to handle human excreta. In China, cartage systems (such as that in Figure 8.9) remove excreta from houses and transport them by hand, truck or boat to agricultural areas where they are applied to the fields. Hygienic problems arise if the excreta contaminate the workers (as in the poem) or if excreta are applied raw to the fields (as is common in China, now that most of the commune composting brigades have been disbanded)
Source: From McGarry and Stainforth (1978). Reproduced by permission of the International Development Research Centre

city of Melbourne, Australia, supports a herd of 13 000 cattle and up to 30 000 sheep. Wastewater and sludge from the city of Braunschweig in Germany have been used since 1971 to irrigate 2 800 ha of land belonging to a number of farmers. Since 1984 in the town of Kearney, Nebraska in the USA the sludge from the wastewater treatment plant is mixed with animal manure and composted, before spreading on 1200 ha of land on which maize is grown; the increased humus content improves the water retention of the sandy soil, and the nutrients in the compost avoid the need for artificial fertilizer, except for supplemental nitrogen.

These and other cases show that wastes *can* be used safely. However, it is also clear that the uncontrolled use of untreated human wastes can pose a health risk, especially to farm workers and crop handlers, but also to the consumers of some edible crops.

In the past, it was held that if any pathogen reached the fields it constituted a potential risk to health. It followed that the only safe precaution was to require treatment of the wastes to remove *all* pathogens, so that this could not occur. This led to the setting of treatment standards which were practically impossible to achieve. When these were observed, use of the waste was not worthwhile economically. More often, they were ignored and the waste was used informally, with no treatment at all.

A 'potential risk' may not necessarily become an 'actual risk'. Pathogens reaching a field may not contaminate crops (for instance, if fruit trees are irrigated at ground level) or may not survive long enough or in sufficient numbers to infect people; and the population may be immune or take other measures to avoid infection, such as wearing protective clothing. Moreover, a particular infection may have other routes of transmission in the community, so that some of the disease observed may not be associated with waste re-use. The most useful measure of risk, therefore, is the '*attributable risk*' or 'excess risk', which is a measure of the amount of disease associated with waste re-use.

Consideration of attributable risk represents a change from microbiological to epidemiological criteria. Its assessment requires epidemiological studies comparing the health of two populations, one exposed to the wastes and one which is not. Reviews of existing epidemiological studies (Feachem and Blum, 1985; Shuval *et al.*, 1986) have led to a reassessment of the health risks of waste re-use in agriculture, with two main conclusions.

First, full treatment of the wastes is not the only way to protect the health of workers and consumers. Other measures can be used to protect these groups from infection (Figure 14.2). Briefly they are the following:

- *Application* Careful choice of the method of application of the wastes can help to control the risk. For example, localized (trickle, drip or bubbler) irrigation reduces both the risk of crop contamination and the exposure of workers to the wastewater; application of excreta before planting is less risky than application during the growing cycle; it will also help to reduce risks if wastewater irrigation ceases several weeks before the harvest.
- *Crop restriction* For example, consumers will be safe from infection if industrial crops such as cotton, sisal, or timber are grown; animal fodder crops, or grains for processing into flour, will also reduce the risk to human consumers.
- *Human exposure control* This includes a number of measures such as wearing protective clothing, immunization and de-worming of farm workers, and also milk pasteurization and meat inspection where pasture or fodder crops are grown using the waste.

Judicious combinations of these, often with partial treatment, can be sufficient to protect the health of all concerned. Some such combinations are shown in Figure 14.3.

Second, the highest risk from the use of untreated wastes relates to infection with intestinal nematode worms, particularly *Ascaris*, *Trichuris* and hookworm. This affects farm workers, whatever crop is grown, and also consumers of some edible crops. There is generally a lower attributable risk from bacterial and protozoal enteric infec-

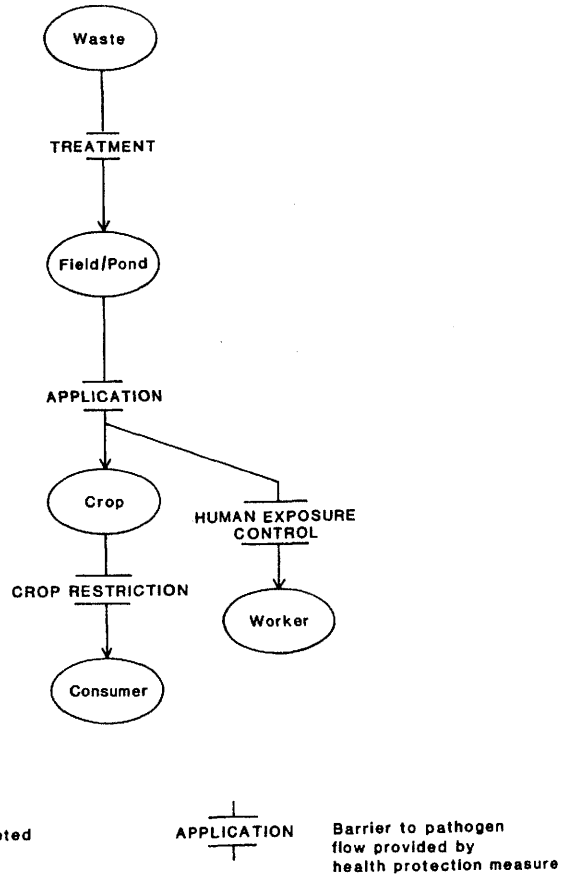

Figure 14.2 Effect of health protection measures in interrupting the potential transmission routes of excreted pathogens

tions, and less still from viruses. Because of this, the WHO quality guideline for treated wastewater to be used for irrigation was made stricter by requiring a maximum of 1 nematode egg per litre. On the other hand, the bacterial standard was relaxed to allow a geometric mean of 1000 faecal coliforms per 100 ml (Table 14.1). Both of these guideline values can be achieved by a well-designed system of stabilization ponds (see Chapter 10), or by upgrading a conventional treatment plant through the addition of one or more ponds.

For sludge and nightsoil, composting is generally the appropriate treatment process, and should preferably be aerobic (see Chapter 13). Twelve months may be necessary to remove the hardy pathogens

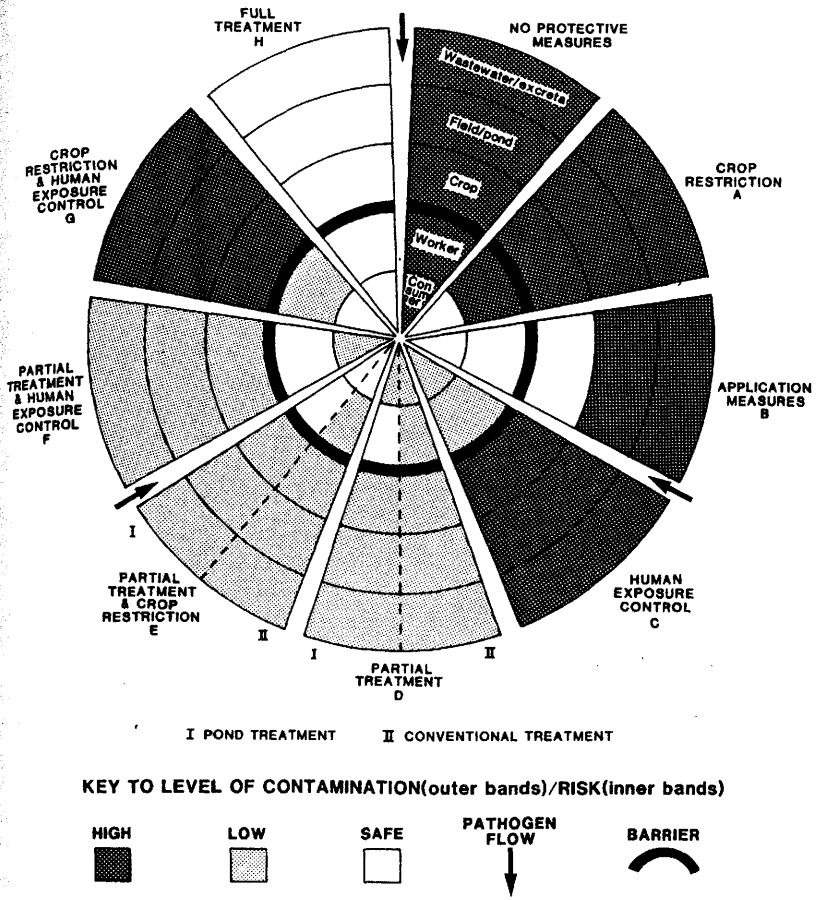

Figure 14.3 Generalized model to show the level of risk to human health associated with different combinations of control measures for the use of wastewater or excreta in agriculture or aquaculture

(notably *Ascaris* eggs) from an anaerobic compost pile, but forced aeration composting can kill them in one month.

There is some concern in the industrialized countries over the presence of heavy metals in urban sewage sludge used as fertilizer, particularly lead, mercury, zinc, and most importantly cadmium. These metals are less likely to be present in the developing countries, but they are not entirely removed by sewage treatment works, tend to accumulate in the soil over the years, and can be taken up by cereals and other crops. In many cases, the concentration of toxic chemical pollutants in wastewater is reduced by about 50% by sedimentation.

Table 14.1 Recommended microbiological quality guidelines for wastewater use in agriculture[1]

Category	Reuse conditions	Exposed group	Intestinal nematodes[2] (arithmetic mean[3] no. of eggs per litre)	Faecal coliforms (geometric mean[3] no. per 100 ml)	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks[4]	Workers, consumers, public	≤ 1	≤ 1000[4]	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, pasture and trees[5]	Workers	≤ 1	No standard recommended	Retention in stabilization ponds for 8–10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

[1] In each specific case, local epidemiological, sociocultural and environmental factors should be taken into account, and the guidelines modified accordingly.
[2] *Ascaris* and *Trichuris* species and hookworms.
[3] During the irrigation period.
[4] A more stringent guideline ($\leq$ 200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.
[5] In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

Since the volume of settled sludge is about one-half of one per cent of the volume of sewage, each constituent that is transferred to the sludge is then concentrated about a hundredfold. Where heavy metals are present in sludge in a significantly higher concentration than in animal manure, the quantity of sludge to be applied should be limited. In Sweden, for example, it is recommended that not more than 1 t/ha.year (dry weight) of sludge should be applied to the land.

14.3 HEALTH AND FISH FARMING

Aerobic ponds containing sewage or nightsoil typically support large growths of algae. These may be used to support populations of fish, which can be harvested for consumption. For example, 44 km^2 of ponds, fed with raw wastewater from Calcutta, produce over 1 ton/ha of fish (carp and tilapia) each year, amounting to 10–20% of all the fish consumed by the city's 11 million inhabitants. Three health problems are potentially associated with the use of excreta to fertilize fish ponds.

(1) *Passive transference of pathogens by fish* Although fish do not suffer from any human bacterial pathogens, if faecal bacteria are very numerous in the pond water they may accumulate on the surfaces or in the intestines of the fish. WHO (1989) has therefore suggested a tentative bacterial quality guideline for the pond water of not more than 1000 faecal coliforms/100 ml. The level in the wastewater entering the pond can be several times greater than this, since the wastewater is usually diluted in the pond. Keeping the pond water quality within the guideline will also help to protect the health of the fishery workers who are in contact with it.

Keeping the fish in clean water for 2 to 3 weeks before harvest, known as 'depuration', will further reduce any faecal contamination of the fish and also remove any residual objectionable odours. A promising alternative is to grow 'trash' fish such as tilapia in waste-fertilized fish ponds and then feed them to high-value fish.

(2) *Transmission of some helminths for which edible fish, shellfish, crustaceans or plants are intermediate hosts in the life cycle* The most important of these are the Chinese liver fluke *Clonorchis sinensis*, cat liver flukes *Opisthorchis* spp., the fish tapeworm *Diphyllobothrium latum*, and the intestinal fluke *Fasciolopsis buski*. The first three of these infect man when insufficiently cooked fish are eaten, and the last is found on edible water plants such as water chestnut. All of them are only found in certain parts of the world, particularly South-east Asia and the Far East (Figure 14.4). Their life cycles are listed in Appendix C, and distribution maps are given by Feachem *et al.* (1983).

In countries where these parasites are not found, they are unlikely to be introduced by aquaculture alone, as all of these flukes depend for their transmission on specific species of snail. Where they are endemic, the wastes should be treated to kill any of their eggs which might be present. For example, storage of nightsoil or sludge for 7 days before addition to the ponds is perfectly adequate to remove *Clonorchis* and *Opisthorchis* eggs. However, the effect of waste-fed fish ponds on the transmission of these parasites is often minor in comparison with other bodies of water where fish or water plants are taken for consumption, which may be contaminated by indiscriminate defecation, by the use of overhang latrines, or by animals,

Figure 14.4 Raw nightsoil is poured into fishponds in Taiwan. This practice is widespread in East and South-east Asia, and greatly contributes to fish production and thus to dietary protein. However, major health hazards are involved unless the nightsoil is first pre-treated to remove various pathogens (Photo: M McGarry)

since the eggs of all of the parasites concerned can also be found in the faeces of vertebrate animals other than man.

(3) *The risk to fishery workers of schistosomiasis* This is only a concern in those parts of the world where one form or another of schistosomiasis is endemic (see Chapter 17), and where the local vector species of snail is likely to breed in fish ponds. Certainly, fishermen are at increased risk of schistosomiasis in many communities in Africa and China.

Storage of the wastes before adding them to ponds is an effective treatment measure. In China, storage of faeces with urine in warm weather killed schistosome eggs in 3 days by ammonia toxicity; adding urea, ammonium bicarbonate and calcium cyanamide, at 1%, 0.5% and 0.25% respectively, kills them in 24 hours (Edwards 1992). These measures are likely to be more effective in Africa or Brazil,

because the eggs of *Schistosoma mansoni*, which is endemic there, are less robust in the environment than those of *S. japonicum*, the species found in the Far East.

Removal of aquatic vegetation from the banks of a pond makes it more likely (although not certain) that it will not harbour snails. However, biological control with snail-eating fish has not proved promising; large numbers of snails have been found in dense patches of vegetation, presumably where the fish could not reach them. The tilapia *Oreochromis mossambicus*, which is a predator of snail eggs and young, seems to offer more hope.

Other forms of exposure control, such as chemotherapy and protective clothing for the pond workers, are also appropriate, and feasible when the operation is carried out on a limited scale such as a set of waste stabilization ponds. The success of environmental schistosomiasis control efforts in China, a country where excreta-fed fish ponds are common, suggests that the problem can be kept to manageable proportions by good pond management.

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