# IRCWD NEWS

WHO International Reference Centre for Wastes Disposal

Ueberlandstrasse 133, CH-8600 Duebendorf/Switzerland


"IRCWD News" is issued on the sole responsibility of the WHO International Reference Centre for Wastes Disposal; it does not necessarily reflect the official views and policies of the World Health Organization

No. 23 December 1985

## Health Aspects of Nightsoil and Sludge Use in Agriculture and Aquaculture

*This issue of IRCWD News is devoted entirely to the problems related to the use of faecal wastes in agriculture and aquaculture.*

*In 1982, the International Reference Centre for Waste Disposal (IRCWD), in collaboration with WHO, started a project on the actual (as opposed to theoretical or potential) health risk related to the use of human excreta. A further objective of the project is to highlight sociocultural, technical and institutional aspects of such a practice. In the first phase of the project, three state of knowledge reviews were prepared based on three types of perspectives.* **Part I,** *prepared* **by Piers Cross,** *a sociologist presently working in Harare, Zimbabwe,* **highlights cultural differences in excreta management practices, discusses beliefs and habits, and suggests ways to strengthen the role of sociocultural perspectives in programmes dealing with excreta disposal and hygiene-related problems. Part II presents compiled information** *reviewed* **by Martin Strauss,** *a sanitary engineer working at IRCWD,* **on survival of excreted pathogens in excreta and faecal sludges prior to utilization (i.e. during storage and treatment), and reports about the fate of these pathogens in the soil, on crops and in nightsoil-enriched fish ponds. Part III** *has been* **prepared by Deborah Blum and Richard Feachem** *of London School of Hygiene and Tropical Medicine,* **with the objective to gain an overview of existing documented epidemiological evidence** – *scare as it be* – **regarding disease transmission through nightsoil use as a fertilizer. It determines gaps in epidemiological knowledge and outlines possible approaches to enhance the evidence by field investigations.** *All these reviews, which will be published in due course by IRCWD, are summarized in the first part of this issue of IRCWD News.*

*The reviews presented hereafter focus on the use of excreta, nightsoil and sludge and not on the use of wastewater for agricultural and aquacultural purposes. This separation is artificial and was done for practical reasons only. It is even reasonable to assume that the range of pathogens is the same for both nightsoil and wastewater, and that health risks associated with their use as fertilizers are of similar nature. The World Bank as executing agency for the United Nations Development Programme (UNDP) on the integrated resource recovery project, has commissioned a parallel study on the health effects of wastewater irrigation by a team of consultants headed by Prof. Hillel Shuval. This report will be published end of 1985 by the World Bank in the technical paper series.*

*During July 1–4, 1985, a group of engineers, epidemiologists, and social scientists met in Engelberg, Switzerland, to discuss these state-of-the-art reports on the epidemiological, microbiological, sociological, and technical aspects of excreta and wastewater utilization. Based on these reviews, the meeting, which was jointly called by The World Bank, UNDP, WHO and IRCWD, formulated a model of the health risks associated with the use of untreated excreta and wastewater in agriculture and aquaculture. It issued preliminary recommendations for wastewater and excreta quality standards, and made specific proposals for further applied research in this field. The report of the meeting is published in the second part of this IRCWD News issue.*

### Introduction

Excreta constitute a valuable source of nutrients. In many countries (e.g. China, Taiwan, Japan, Korea, Indonesia) they are traditionally and widely used to fertilize fields and ponds where fish and aquatic vegetables are grown. In these areas, faecal wastes carry considerable economic importance which may increase in the years to come elsewhere too as a result of the growing cost of mineral fertilizers (unaffordable to many farmers) and increasing demand for basic food supplies.

Excreta are presumably utilized in a raw or only marginally treated state in the majority of situations. Such practice leads to potential health risks for those who work in excreta fertilized fields or ponds as well as for those who consume vegetables or fish grown there. Whether, how and to what extent disease transmission and actual health risk are really associated with this practice is, however, hardly known. Neither does one know much about the relative importance of excreta fertilization in comparison with other possible routes of pathogen transmission.

Much effort has been spent over the past decades to investigate the fate of excreted pathogens in the outside-host environment, i.e. in water, wastewater, sludge, soil and on crops. The results are widely documented. The rationale for most of these investigations lies in the intention to use information gathered about pathogen survival for arriving at meaningful judgements regarding health risks of excreta management practices. Thus, an environmental perspective is applied to solve a problem which is largely of an epidemiological nature!

However, inferences based purely on an environmental perspective may lead to intuitive or speculative conclusions. This has important repercussions on excreta or wastewater utilization strategies. While intuitive inferences may constitute a feasible approach in many instances, it certainly does not suffice as a basis for determining the actual health risks of excreta utilization. Fig. 1 shows that pathogen characteristics, anthropological factors and the biology of the human host must interact in a rather complex manner to render possible the transmission of surviving pathogens to a human host and to cause infection in that host. Therefore, an epidemiological perspective is required beside the environmental one to find out about events of actual disease transmission and the particular circumstances associated with them.

Furthermore, an anthropological perspective is needed to enhance knowledge of the sociocultural and behavioural factors which affect human waste management practices and related disease transmission.

## Part I: Existing Practices and Beliefs in the Use of Human Excreta

by Piers Cross, Sociologist, Harare, Zimbabwe.

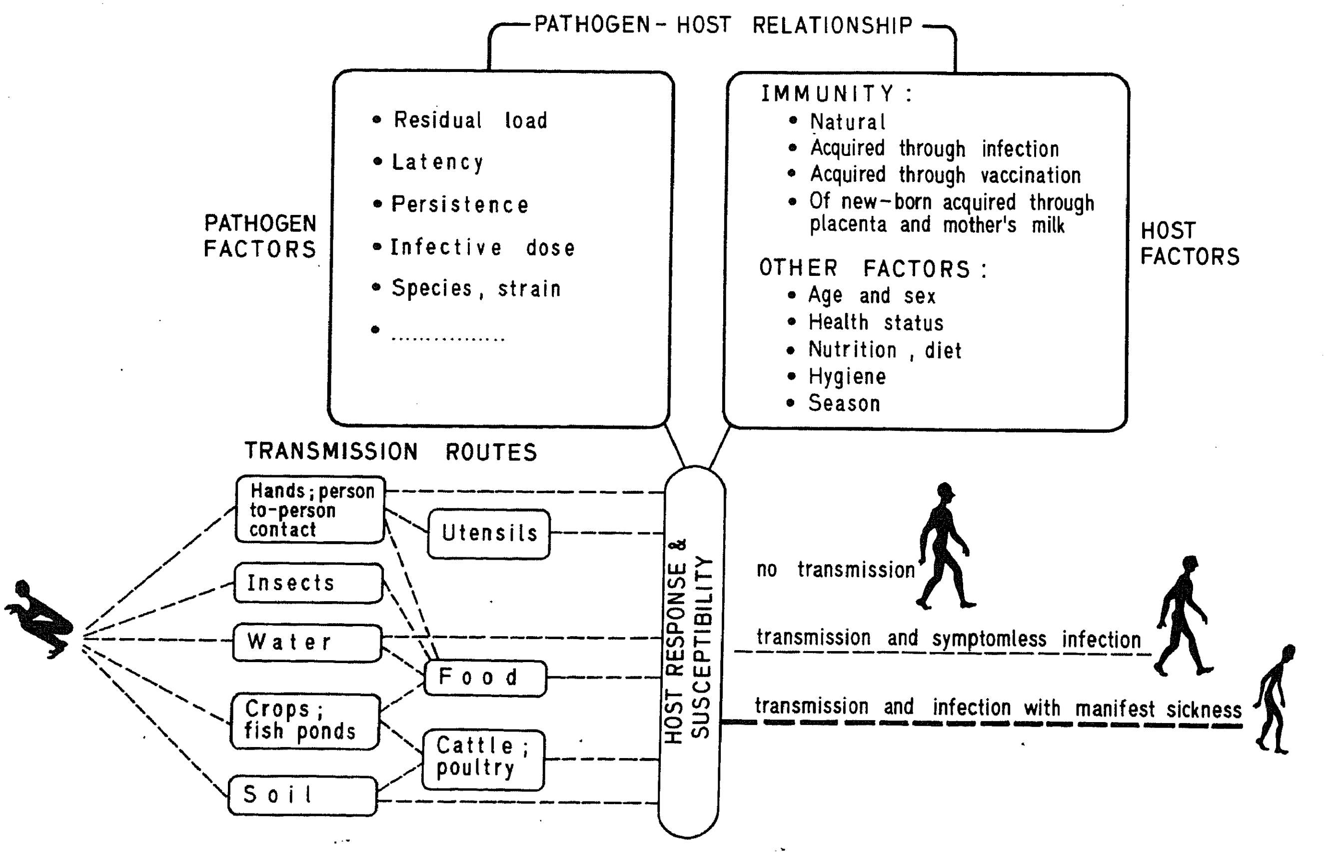
*The Importance of Sociocultural Aspects of Excreta Utilization*

Why should the study of human behaviour be relevant to the prevention of disease transmission and the reuse of nutrients? What are the sociocultural issues of practical importance in considering promotion of nutrient reuse?

To achieve cost-effective interventions in disease transmission, it is necessary to identify the primary routes of pathogen transmission. A first reason why sociocultural data is of importance in environmental health is that changing behaviour is one method of breaking the chain of disease transmission. Before an attempt can be made to change behaviour, it is necessary to have an understanding of the prevailing practices.

A second reason for considering sociocultural factors is that patterns of human behaviour are shaped, among other important factors (such as physical environment

Fig. 1:
**The Pathogen-Host Relationship and Possible Transmission Routes for Excreta-Related Infections**



etc.), by a cultural domain, by social and economic pressures and by volition. In order to change a pattern of behaviour it may be necessary to change factors which determine that behaviour. A full understanding of behaviour requires knowledge of a range of cultural, social and economic factors.

A third reason why it is important to have a knowledge of the sociocultural dimension is that proposals to encourage utilization of human excreta, or indeed affect behavioural change in any culturally sensitive area, will have limited success unless the changes are culturally acceptable. Where proposed changes are culturally unacceptable, a knowledge of local cultural values and practices will be of significance in seeking to develop a strategy to make proposed changes more acceptable, or indeed to reject proposed innovations.

### *Cultural Variation in Excreta Utilization*

Human society has developed culturally diverse responses to the problem of disposal or (depending on how it is viewed) challenge of utilization of human excrements. The global categorization of cultures according to their attitude towards utilization of human excreta is complicated by the range of uses to which human excreta is put, and the diversity of social units which utilize nutrients from human excreta.

These facts, together with the shortage of published social field studies on this most private aspect of social life, prevent the development of a global cultural guide reflecting utilization of human excreta. Table 1 gives an indication, however, of the range of excreta utilization practices in different countries.

Since the present state of accessible knowledge is insufficient to exhaust the range of sociocultural responses to excreta utilization, the review presents three case-studies which illustrate categories of cultural variation. These are:

1. An area in which excreta utilization is an ancient and well accepted custom (China);
2. An area in which use of excreta is abhorred (certain cultures of Islamic religion);
3. An area in which excreta utilization is little practised but where there are no overriding religious convictions prohibiting its usage either (Subsaharan Africa).

***The Chinese case study*** is perhaps the most remarkable in nutrient reuse, both in the extent of the practice of excreta use and in the pragmatic government policies adopted. The mass programmes to promote sanitation and nutrient reuse are undoubted reflections of a commitment to improving the rural environment and rural production. At the same time, they are consistent with Chinese traditions of frugality, and they propose practices within an ancient framework of ideas regarding excreta disposal and usage. While practices have been made more efficient and appear less injurious to health, the indigenous cultural understanding of relations between man, his bodily products, the fertility of the soil, and food production has not changed. Similarly, a reason for the successful development of double-vault composting latrines in Vietnam is undoubtedly largely attributable to a prior cultural acceptance of the use of human excreta in agriculture.

Table 1:
**Range of Human Excreta (Utilization) Practices with Developing Country Examples**

| Practice | Social Unit | Examples |
|---|---|---|
| 1. Soil fertilization with untreated or stored nightsoil | family or community | China, Korea, Taiwan, Japan, Thailand |
| 2. Nightsoil collected and composted for use in agriculture | community or local authority | China, India |
| 3. Nightsoil fed to animals | family | Melanesia, Africa |
| 4. Use of composting or mouldering latrines | family | Vietnam, Tanzania |
| 5. Biogas production | family or community | China, India, Korea |
| 6. Fish pond fertilization with treated or untreated nightsoil | family or community | Taiwan, Korea, China, Malaysia, Indonesia |
| 7. Fish farming in stabilization ponds | family (illegal) or local authority | India, Israel |
| 8. Aquatic weed production in ponds | family, community or local authority | Vietnam, S E Asia |
| 9. Agricultural Application of sewage | local authority or commercial farmer | India, South Africa |
| 10. Irrigation with stabilization pond | local authority or commercial farmer | Israel, India |
| 11. Algae production in stabilization ponds | local authority | Mexico, Japan |

In contrast to the Chinese tradition, in ***Islamic cultures,*** Muslims profess the avoidance of all contact with human excreta. Excreta and urine, along with semen, corpses and other specified substances are regarded as spiritual pollutants by Koranic edict, and Islamic custom demands that Muslims minimize contact with these substances. Muslim principles of personal hygiene include: ablution with water after elimination; using only the left hand for contact with the anal area and using the right hand for human contact and when eating; and forbidding contact with (or the consumption of) dogs, pigs or other animals which eat carrion or waste matter. Despite the power, influence and clarity of Islamic law with regard to contact with human wastes, in practice, resource constraints, and religious, ideological and cultural variations lead to different practices. For instance the direct application of nightsoil to fish culture in West Java, Indonesia, is an ancient cultural practice which has altered little under Islamic rule. In other places, the use of wastewater for restricted irrigation has been declared compatible with Islamic precepts provided specific requirements regarding treatment and use are adhered to. As an example, reuse of municipal wastewater is widely practised in Tunisia and has recently started in Saudi Arabia.

***Subsaharan Africa*** is shown as an area in which excreta utilization is little practised but where there are no overriding religious convictions prohibiting its usage either. The African continent contains a great diversity of cultures, however, the cultural traits which bind the continent are not subordinate to an embracing system of thought as in the Islamic world or in China. Reports from a great many African societies show that a disaffection for contact with human excreta is a custom common to most, if not all African cultures. Human excreta are commonly regarded as defiling, and those who touch them are distanced from the main body of society. As excrements are considered a measure of protection by the body against pollution, in African cities where nightsoil is collected, the municipal workers responsible for bucket collection are often regarded as being of inferior status. Notwithstanding these generalizations, there are several examples of instances of excreta utilization in Africa. Within Africa's sprawling peri-urban populations, there are reports of ingenious informal sector uses for a variety of waste products. Fishing (often illegally) in waste stabilization ponds is reported from several cities (for example the Kenyan city of Kisumu). Fish farming in sewage ponds is also formally endorsed by several local authorities (for example in Lusaka). The formal sale of sewage sludge by local authorities has long been established in many cities, most notably South Africa where there is an extensive public health legislation controlling the use and sale of sludge.

## Conclusions and Recommendations

Based on his literature review, the author draws the following conclusions and recommendations:

Social and cultural problems severely constrain the implementation of several technologies utilizing human excreta that might otherwise contribute to ease resource constraints in poor countries.

The most prominent sociocultural question asked when considering use of human excreta is: is excreta usage culturally acceptable? This is an important question, however, its importance relative to other sociocultural and programme-management questions may have been overstated. Excreta utilization technologies of real benefit to a populace, affordable and not entailing unacceptable social costs, may well gain acceptance even where there are religious or cultural taboos to the concept of using human excreta. It is moreover not a question which can always be simply answered. Firstly, because cultures are rarely homogeneous and frequently contain a complexity of subcultures with quite different orientations. Secondly, because cultures are not fixed entities; values, beliefs and customs change and can be made to change. Thirdly, because the most appropriate study methodology for gathering data on this culturally sensitive area, principally social anthropological fieldwork, has rarely been employed.

Therefore, an urgent need remains for detailed field studies of social, cultural and behavioural aspects of human excreta reuse. What is required is not research into technologies with a minor social research component, but mainstream research into the behavioural, cultural and social aspects of the implementation and improvement of reuse technologies. Aspects of this research might be purely theoretical, such as in analysis of the meaning and position of particular cultural traits. The emphasis, however, should be placed on applied research in which, for example, different technologies or communications support components are piloted and closely monitored with the objective of learning about social and educational aspects of the use of human excreta rather than restricting investigation to technical performance.

Further sociocultural research into excreta utilization is recommended in two general areas.

*1. Detailed studies of existing defecation and excreta utilization practices in cultures which practise excreta reuse.* These are necessary in order to develop our understanding of actual health risks of the use of excreta, and to develop strategies for minimizing the risks of disease transmission.

*2. Applied field research into user's response to excreta utilization innovations.* Applied field research monitoring of user's response to a variety of innovations and modifications to excreta utilization is necessary. Special emphasis should be given to experience with cultures where contact with excreta is considered culturally unacceptable. The objective is to pilot excreta use projects so as to examine the potential for changing cultural attitudes in a variety of cultures.

## Part II: Survival of Excreted Pathogens in Faecal Sludge, on Soils and on Crops

by Martin Strauss, Sanitary Engineer, IRCWD, Switzerland.

This part comprises the state of knowledge review on excreted pathogen survival during storage and treatment and after application on crops, in soil and in fishponds.

### *Principle of Pathogen Survival*

All pathogens will eventually die or lose infectivity after excretion and release into the extra-host environment. In general, the reduction of viable pathogens is exponential, i.e. there is a rapid decrease in numbers in the first few hours or days after excretion, with a reduced number surviving over an extended period. Variations of this die-off pattern are found with a few bacteria (e.g. ***Salmonella***) which may temporarily multiply outside the host, and with most helminths which have one or more non-infective intermediate development stages with typical die-off patterns. A further variation is found with trematodes (e.g. *Schistosoma, Chlonorchis sinensis*), which have a multiplication phase in intermediate hosts.

Basically, pathogen die-off follows the same exponential-type pattern independent of the kind of environment (such as in soil, on crops, in sludge, or in excreta stored in a latrine or leaching pit). Particular environmental factors, however, determine the actual die-off rate and the number of organisms surviving with a given time period. This, in turn, determines the time required to obtain a "safe" or "reasonably safe" product. From a wide range of relevant references, the main environmental factors which influence pathogen die-off are listed in Table 2.

### *Survival during Storage and Treatment*

Pathogen survival patterns during excreta storage and treatment are summarized in Tables 3 and 4. Under ideal conditions, most systems can yield a product which has very low or undetectable levels of viable pathogens, as can be seen in Table 3. Pit and pour-flush latrines represent excreta disposal systems which, if properly built and

Table 2:
**Major Environmental Factors Influencing Pathogen Die-Off**

| Environmental factor | Effect on pathogen die-off or survival |
|---|---|
| · Temperature | — Accelerated die-off with increasing temperature, longer survival at low temperature |
| · Moisture content (of foods or soils or in waste products), humidity | — Generally longer survival in moist environment and under humid weather conditions, rapid die-off under conditions of desiccation |
| · Nutrients | — Accelerated die-off if essential nutrients are scarce or absent |
| · Competition by other microorganisms | — Longer survival in an environment with few or no microorganisms competing for nutrients or acting as predators |
| · Sunlight (ultra-violet radiation) | — Accelerated die-off if exposed to sunlight |
| · pH | — Neutral to alkaline pH tends to prolong survival of bacteria; acid pH tends to prolong survival of viruses |

operated as alternate twin-pit systems, will fulfill strict pathogen removal standards. A few eggs of *Ascaris lumbricoides* may remain viable. Whether this carries much epidemiological significance is, however, not well known yet. Systems likely to yield unsatisfactory products are aqua privies, septic tanks and biogas digesters, none of which are designed for pathogen removal or inactivation.

However, ideal conditions are hardly ever met. Therefore, the objective of Table 4 is to suggest survival patterns as may be expected "in practice", i.e. under real-world conditions, where conceptualization, system construction, use and maintenance tend to be non-optimal. None of the listed systems will then yield products which are hygienically "safe". Consequently, potential health risks are associated with the handling and use of such products. However, the actual (as opposed to the potential) risk of disease transmission and the epidemiological relevance related to the use of only partially treated nightsoil are not clear yet.

### *Survival in Soil and on Crops*

After disposal on land, the process of pathogen die-off continues although at different rates for each type of pathogen.

The question whether there is a potential risk of pathogen transmission through soil or crop in a particular situation, depends on numerous factors. Pathogen survival or die-off is dependent on the organism's persistence and the

Table 3:
**Summary: Survival of Excreted Pathogens During Pre-Application, Storage and Treatment: IDEAL-World Situation**

| Storage/Treatment System | Ideal-World System Characteristics Relevant to Pathogen Die-off/Survival | Survival of Pathogens | | | |
|---|---|---|---|---|---|
| | | Helminths | Viruses | Bacteria | Protozoa |
| · Pit-Type Latrines: | | | | | |
| - Pit Latrines w. 1 Pit | Latrine abandoned when pit is full; contents let to rest for t ≥ 1 year | ◑[3] | ○ | ○ | ○ |
| - Pit Latrines w.2 Pits | t ≥ 1 year | ◑[3] | ○ | ○ | ○ |
| - Composting Latrines | t = 6 - 10 months; aerobic composting | ○ | ○ | ○ | ○ |
| - Pour-Flush L. w. 1 Pit | (Handling of fresh excreta when emptying pit) | ● | ● | ● | ● |
| - Pour-Flush L. w.2 Pits | t ≥ 1 year | ◑[3] | ○ | ○ | ○ |
| · Aqua Privies and Septic Tanks[1] | Continuously operated systems: always contain portions of fresh excreta at times of emptying | ● | ● | ● | ● |
| · Thermophilic Composting | $T = 50\text{-}70^{\circ}C$, t ≥ 2 days<br>$T = 40\text{-}45^{\circ}C$, t ≥ 1 week<br>for all parts of waste piles | ○ | ○ | ○ | ○ |
| · Biogas Digesters | t ≥ 60 days, $T = 30\text{-}35^{\circ}C$; effluent draw-off from bulk slurry not from settled sludge | ● | ◑ | ◑ | ○ |
| · Waste Stabilization Ponds[2] | t ≥ 20-30 days; min. 3 cells in series; no short-circuiting | ○ | ○ | ○ | ○ |

○ - zero or near-zero survival
◑ - survival in low concentrations
● - survival in substantial "
t - excreta retention time
T - temperature

[1] Survival in sludge
[2] Survival in treated wastewater (assumption that desludging is not required)

[3] Possible survival of *Ascaris* eggs

Table 4:
**Summary: Survival of Excreted Pathogens During Pre-Application, Storage and Treatment: REAL-World Situation**

| Storage/Treatment System | Real-World System Characteristics Relevant to Pathogen Die-off/Survival | Survival of Pathogens | | | |
|---|---|---|---|---|---|
| | | Helminths | Viruses | Bacteria | Protozoa |
| · Pit-Type Latrines: | | | | | |
| - Pit Latrines w. 1 Pit | Handling of fresh excreta if pits are (or have to be) emptied immediately upon becoming full; | ● | ● | ● | ● |
| - Pit Latrines w.2 Pits | Handling of fresh excreta when emtying twin pits which have been in simultaneous use; | ● | ● | ● | ● |
| - Composting Latrines | Insufficient or no addition of complementary organic wastes; anaerobic, ambient temperature conditions; t < 1 year; | ● | ○ | ○ | ○ |
| - Pour-Flush L. w.2 Pits | t < 1 year; alt'g. use of twin pits; | ◑ | ◑ | ○ | ○ |
| - Pour-Flush L. w.1 Pit | handling of fresh excreta during emptying | ● | ● | ● | ● |
| · Aqua Privies and Septic Tanks[1] | Continuously operated systems; always contain portions of fresh excreta at time of emptying | ● | ● | ● | ● |
| · Thermophilic Composting | $T \leq 40\text{-}50^{\circ}C$; $t \leq 1$ month; not all parts of waste piles subjected to sufficiently high temperatures | ◑[2] | ◑ | ○ | ○ |
| · Biogas Digesters | $T \leq 20\text{-}25^{\circ}C$; t < 1 month; withdrawal of bottom sludge where helminths and protozoa concentrate | ● | ◑ | ◑ | ◑ |
| · Waste Stabilization Ponds[3] | t < 20 days; shortcircuiting; system having less than 3 cells in series | ○ | ◑ | ◑ | ○ |

○ - zero or near-zero survival
◑ - survival in low concentrations
● - survival in substantial concentrations

[1] Survival in sludge
[2] *Ascaris* and possibly also some hookworm, *Taenia, Schistosoma* and *Trichuris* eggs
[3] Survival in treated wastewater

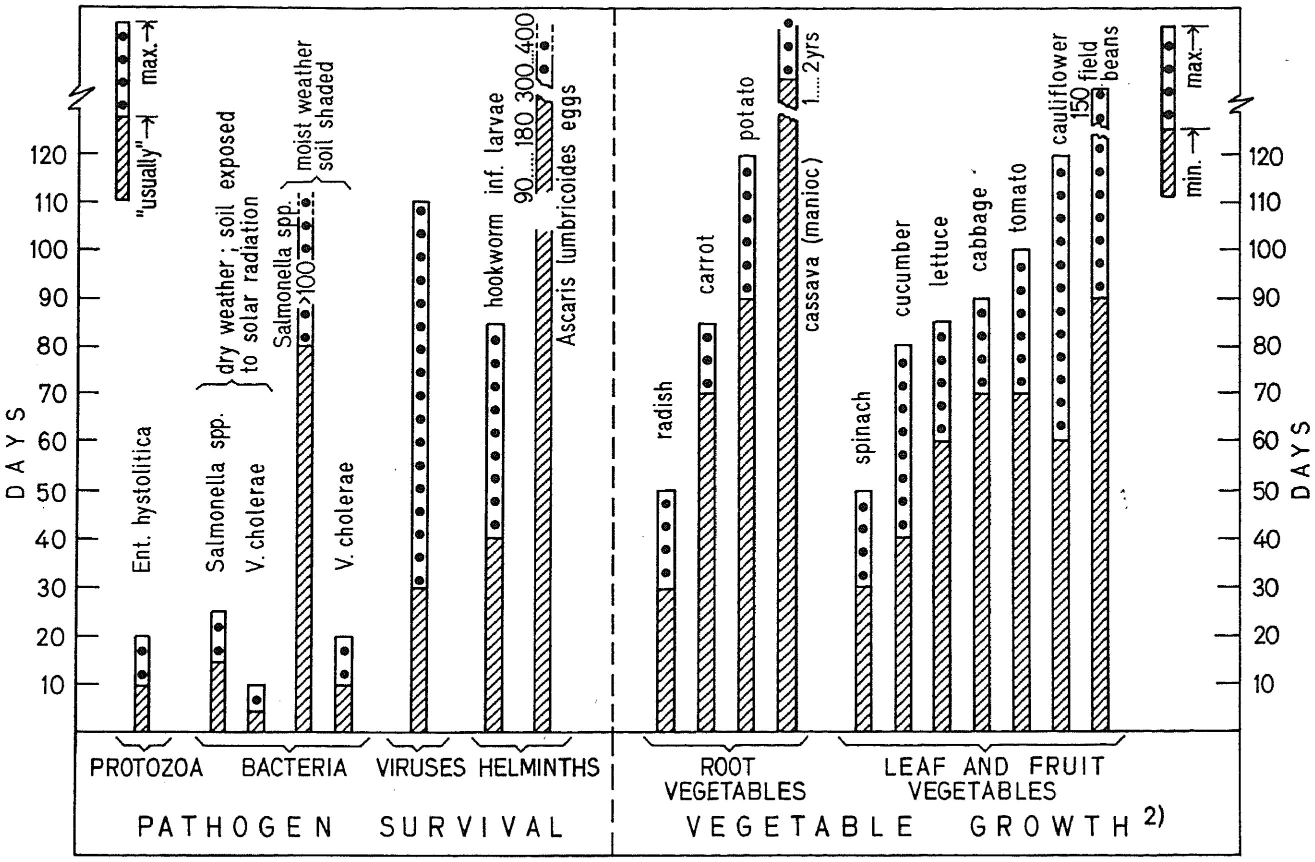
adverse environmental effects such as sunlight, desiccation, shading and soil properties (see also Table 2). Residual pathogen levels on root-crops are expected to be higher than on crops growing above ground because the exposure of root-crops to sunlight and desiccation is lower. Contamination of crops is dependent on the time and method of excreta application to the field. Contamination of leaf and fruit crops is likely to be minimal or nil if the excreta is applied prior to ploughing, sowing or transplanting. However, crops may become contaminated through rainfall splashing or if they fall on the ground before they are harvested. The interval at which nightsoil is applied to the field also plays a role. The potential risk of pathogen transmission to farmers and to consumers of nightsoil-treated crops is most likely to be greater if nightsoil is disposed of repeatedly on the same field during the crop growing period than if nightsoil fertilization takes place only during the initial phase of the growing season. Finally, the potential risk to those working in the field depends on the "risk behaviour" of the workers, i.e. protective measures at work such as the wearing of shoes or boots (particularly to protect against hookworm and schistosoma infection), and habits of personal hygiene such as the washing of hands and body.

Most pathogens are inactivated within the first few hours or days after excretion. However, a few organisms will remain alive and infective for prolonged periods of time. Thus, the length of the time period between nightsoil application to a field and cultivation or harvesting is decisive for the risk of pathogen transmission through either soil or crops. Therefore, if nightsoil is applied only at the beginning of the growing season, an important question is whether excreted pathogens will die off within the growth period of the vegetable, or whether large numbers of pathogens will remain infective even at the time of harvest.

In Figs. 2 and 3, vegetable growth periods and excreted pathogen survival times in soil and on crops are presented in a comparative form for warm climates.

Figure 2, which illustrates survival in soil, shows that ***Ascaris lumbricoides*** eggs have normal survival times which tend to last longer than the period required by most vegetables to reach maturity. Excreta-fertilized crops are therefore potential transmitters of ***A. lumbricoides*** eggs where ascariasis is endemic. Hookworm larvae, though normally dying off substantially faster than ***A. lumbricoides,*** have survival periods in soil which are of the same order of magnitude as the growth period of vegetables such as

Fig. 2:
**Pathogen Survival in Soil vs. Vegetable Growth Periods in Warm Climates** [1)]




1) Determined under widely varying conditions
2) Maturation period from transplanting or from sowing if not transplanted

radish, spinach and cucumber. They pose an occupational risk to those who perform weeding and thinning work in the nightsoil-fertilized fields. *Ascaris* eggs, apart from being transmissible via crops, may also be carried into farmers' homes on the feet of those who work in the fields.

If environmental conditions favouring survival prevail (moisture, shading), a few *Salmonella spp.* survivors might be found in the soil throughout the growth period of several crops. Viruses too may outlast vegetable growth periods. Under harsh conditions, and for other bacteria as well as for the protozoal pathogens, however, survival periods in soil tend to be shorter than the growth periods of plants.

As a rule, survival of pathogens on crops (illustrated in Fig.3) tends to be substantially shorter (in the order of more than two times) than survival in soil. This is not unexpected since pathogens are subjected to harsher environmental impacts (solar radiation, desiccation, temperature) on crops, notably high-growing crops, than in soil. The majority of pathogens exhibits survival periods which are normally shorter than the growth periods of most vegetables. Exceptions have been observed with eggs of *Ascaris* or *Taenia saginata,* as well as with *Salmonella* on root and low-growing crops.

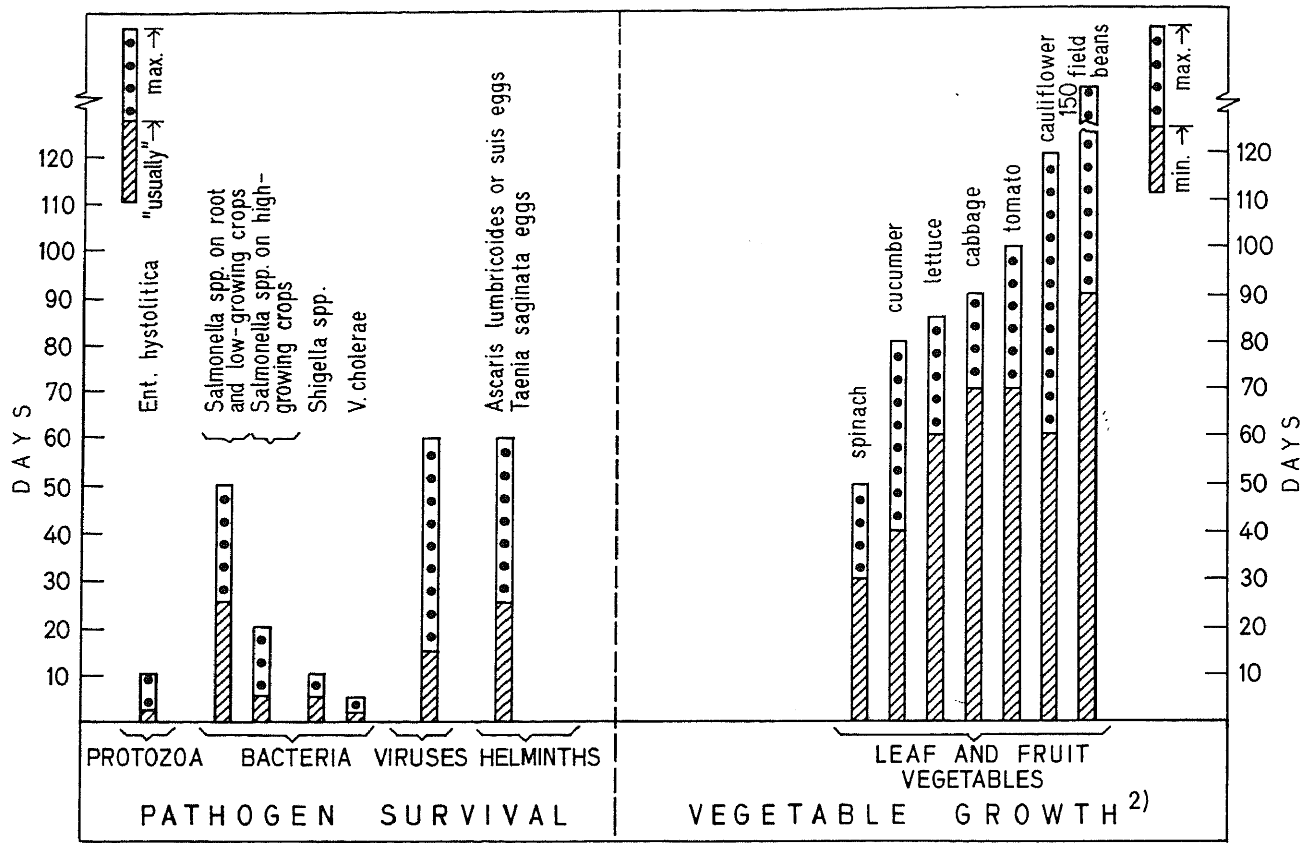
## Conclusions and Recommendations

There is a potential risk of pathogen transmission through nightsoil-fertilized soils and vegetables. In the context of nightsoil utilization, ***helminths, salmonella spp., viruses and protozoa*** are the relevant excreted pathogens ranked in decreasing order of importance. Risks of transmission may arise through the consumption of root or low-growing vegetables which become contaminated during nightsoil fertilization. There are also potential risks to those working in nightsoil-fertilized fields and when handling contaminated vegetables.

The likelyhood that surviving pathogens are present in soil and on crops at the time of harvest is high if the faecal wastes are repeatedly applied while the crops are growing or even shortly before they are harvested. In contrast to this, the potential risk of transmission is minimized if nightsoil is applied only before or in the early phase of the plant growing period.

In order to minimize both workers' and consumers' risks, it is important that excreta are stored or suitably treated prior to use on fields or in ponds. "Best" treatment is determined by the characteristics of the faecal wastes, the kind of excreta-related infections prevalent in the area, existing patterns of excreta handling and use, economic aspects,

Fig. 3:
**Pathogen Survival on Crops vs. Vegetable Growth Periods in Warm Climates** [1)]




1) Determined under widely varying conditions
2) Maturation period from transplanting or from sowing if not transplanted

and the role of institutional and communal organizations in nightsoil management.

In principle, pathogen inactivation can be achieved by a suitable combination of time and temperature. Subjecting nightsoil to extended storage periods at ambient temperature or, alternatively, to high temperature during correspondingly shorter periods, are basic treatment options available.

Based on the existing knowledge of excreted pathogen die-off and the potential risks of transmission of surviving pathogens through nightsoil fertilization, the following recommendations can be made:

- Where nightsoil utilization is planned to be introduced, the possibility of untreated nightsoil use should obviously be discouraged: (1) in order to avoid introduction of potential pathogen transmission routes previously unknown in the area and (2) for aesthetic reasons. Such a rule will be readily accepted by most cultures without excreta utilization tradition as they abhor handling and use of fresh human faecal wastes.

- Where nightsoil is traditionally used without prior storage or treatment, efforts should be made to store the excreta prior to their use on fields or in ponds[1]. The length of "safe" storage periods can at this stage not be determined with confidence since related epidemiological evidence is lacking. Actual knowledge of pathogen survival in faecal wastes indicates that at ambient temperatures in warm climates, two to three weeks would be a minimum desirable storage period, allowing for considerable pathogen reductions. To obtain a product which can be used for unrestricted fertilization[2], several months of storage are required. Storage of nightsoil may take place in storage pits or tanks centrally located to receive the faecal wastes collected from individual latrines. Latrines with alternate twin-pits also provide several months of storage time as the contents of the first full pit is left to decompose, while the alternate pit is in use. Therefore, the nightsoil from the first pit will practically be free from active pathogens after having been stored for half a year or more. *Ascaris* eggs may be the only survivors (Table 3). Dry-disposal double-pit latrines and pour-flush latrines with twin leaching pits are suitable choices for latrine systems where excreta utilization is practised.

[1] This is obviously not a viable measure where latrines are purposely placed over ponds.
[2] i.e. fertilization of root or low-growing crops eaten raw

Treatment of nightsoil in wastewater stabilization ponds may constitute a feasible solution in areas where large volumes of nightsoil or other faecal wastes are regularly collected, and where utilization of nightsoil is not sought or otherwise possible. Methods of thermophilic composting of mixtures of nightsoil and other organic residues such as manure or plant wastes should be tried or promoted if prospects of cultural acceptability and economic feasibility are good. Properly composted nightsoil carries very little if any loads of viable pathogens (Table 3).

Potential risks of pathogen transmission through nightsoil-fertilized crops and soil can be reduced by allowing long time periods to pass between nightsoil application and the working in the field or before harvesting. Thus, from a health point of view, optimum results are obtained if nightsoil application is restricted to the fallow periods and the early phases of the plant growing cycle.

## Part III: An Epidemiological Perspective

by Deborah Blum and Richard Feachem, London School of Hygiene and Tropical Medicine, London, U.K.

In order to be able to establish with reasonable certainty actual — as opposed to potential — health risks associated with excreta use, sound epidemiological data are required. Part III of the reviews has been prepared towards this end. It reviews critically and in detail available epidemiological information pertaining to the use of nightsoil and sludge in agriculture and aquaculture. Since there is a scarcity of sound and methodologically reliable data, particularly on the risk attributable to the use of treated excreta, the review therefore proposes epidemiological field investigations to fill gaps in knowledge and to guide future technical policy.

The available epidemiological evidence is based mainly on observations relating to the use of raw nightsoil. The data suggest that certain helminthic infections, notably hookworm and ***Schistosoma japonicum*** may be occupationally acquired under specific circumstances where raw excreta use in agriculture is practised. There is also evidence that the use of raw nightsoil in agriculture is associated with a risk of infection with ***Ascaris*** and ***Trichuris.*** However, some uncertainty remains on the way in which nightsoil promotes the spread of these two infections since studies did not specify adequately the types of nightsoil use and exposure studied. In a number of studies, an association between foodborne disease outbreaks of e.g. amoebiasis, paratyphoid fever and typhoid fever, and nightsoil fertilization of vegetables eaten raw is reported. However, epidemiological data are considered insufficient. This contrasts with a well-documented case of a foodborne cholera epidemic in Jerusalem. There, rather good evidence could be gained that raw wastewater-irrigated vegetables were the likely vehicles of infection.

For zoonotic infections, i.e. infections transmissible from vertebrate animals to man, there is epidemiological evidence of infection of animals through the use of human excreta or sludge on pastures; evidence of subsequent human infection is more limited. There is a risk of cattle becoming infected by certain ***Salmonella*** species and ***Cysticercus bovis,*** the larval stage of the beef tapeworm, ***Taenia saginata.*** For bovine salmonellosis, there are multiple alternative routes of transmission. The potential relative importance of excreta use on pastures in the transmission of salmonellosis in cattle may therefore be small. Transmission of salmonellosis to persons consuming milk from cattle grazing on sludge-fertilized land has been documented on one occasion, and in another instance human cases of salmonellosis resulted after accidental contamination of pasture by wastewater effluent.

For ***T. saginata,*** cattle are the obligate intermediate hosts. This enhances the potential importance of pasture fertilization with excreta in the transmission of beef tapeworm. The relative importance of the purposeful use of excreta in pasture fertilization in relation to open defecation on pastures is unknown. It mainly depends on the cultural and economic setting, i.e. defecation habits, the use of excreta disposal installations, the importance of cattle in the local agriculture, and human excreta use practices. It is reasonable to assume that there is a risk of ***C. bovis*** infection of cattle if raw nightsoil or sewage sludge is used to fertilize pastures. Subsequent human infection depends on food preparation habits in areas where taeniasis is endemic.

There are few epidemiological studies which specifically examine the health risks of the use of excreta in aquaculture. The few studies that were located focus on the risks of infection with certain trematode worms. There is evidence suggesting that consumption of fish grown in raw excreta-fertilized ponds is associated with human infection with ***Clonorchis sinensis*** (Chinese liver fluke) and that consumption of aquatic vegetables grown in such ponds is associated with human infection with ***Fasciolopsis buski*** (intestinal fluke). The extent to which the transmission of these infections occurs through the purposeful use of excreta to enrich ponds, as opposed to incidental faecal contamination of ponds, is unclear. Epidemiological studies examining other infectious disease risks from consumption of foods grown in excreta-fertilized ponds, or examining occupational risks of nightsoil use in aquaculture, are lacking.

Table 5 summarizes the available epidemiological knowledge regarding infectious disease risk from the use of raw nightsoil or sludge in agriculture. The equivalent information for aquaculture is contained in Table 6. The epidemiological studies on which these tables are based are few in number (particularly for aquaculture), generally weak in methodology, examine only a few of the potentially important health risks and focus almost exclusively on the use of raw or minimally treated nightsoil or sludge.

These serious gaps in knowledge require that a new generation of epidemiological studies be developed. The following factors should be considered in selecting the most appropriate and important health risks to study in a given situation: a) the pattern of excreta-related diseases in the area from which the excreta originated; b) the transmission potential of given excreted pathogens in the area using excreta; c) the type and extent of excreta treatment prior to use, and d) the type of use and exposure. It is suggested that consideration be given to the use of cross-sectional and case-control studies as the most cost-effective methodologies for evaluating the health risks of excreta use. Epidemiological studies should examine those risks for which little is known and much morbidity may be expected. These risks include, for agricultural use, the risks to people consuming crops fertilized with treated

Table 5:

**Agricultural Use: Current State of Epidemiological Knowledge on Risks of Human Infection with the Major Groups of Pathogens According to the Type of Use of Nightsoil or Sludge and Type of Exposure**

| Exposure group | Infectious disease risks from nightsoil or sludge fertilization of: crops for humans | crops for animals | non-consumable crops |
|---|---|---|---|
| persons consuming crops | V [B] ·P· (N) | – | – |
| persons consuming meat or milk | – | (B) (C) | – |
| agricultural or sanitation workers at site of use | V̲ B P (N) (T) | V̲ B P (N) | V̲ B P (N) |

V = excreted viruses

B = excreted bacteria

P = excreted protozoa

N = excreted nematodes

C = excreted cestodes

T = excreted trematodes

– = not applicable

V = potential risk: no epidemiological data

(V) = risk supported by epidemiological data

[V] = risk from nightsoil or sludge use likely on the basis of wastewater epidemiological data

·V· = risk reported but insufficient epidemiological data for confirmation

V̲ = risk inconsistently supported by epidemiological data

Table 6:

**Aquacultural Use: Current State of Epidemiological Knowledge on Risks of Human Infection with the Major Groups of Pathogens According to the Type of Excreta Use and Type of Exposure**

| Exposure group | Infectious disease risks from excreta fertilization of: crops for humans | crops for animals | non-consumable crops |
|---|---|---|---|
| persons consuming crops | V B P C (T) | – | – |
| persons consuming meat or milk | – | B | – |
| aquacultural or sanitation workers at site of use | V B P T | V B P T | V B P T |

V = excreted viruses

B = excreted bacteria

P = excreted protozoa

C = excreted cestodes

T = excreted trematodes

– = not applicable

V = potential risk: no epidemiological data

(V) = risk supported by epidemiological data

nightsoil or sludge, and the risks to persons with occupational exposure. For aquacultural use, they include the risks to people consuming fish or aquatic plants grown in excreta-enriched ponds. Future studies should be carried out on a variety of different types of projects in a variety of economic, social and cultural settings. The design and implementation of excreta use schemes, their monitoring and the assessment of health risks must be a multidisciplinary approach[9] involving engineers, epidemiologists and social scientists. Improved routine disease surveillance to aid in outbreak identification and investigation should be encouraged in all areas where excreta use is practised, whether or not specific epidemiological studies are undertaken.

# Health Aspects of Wastewater and Excreta Use in Agriculture and Aquaculture: The Engelberg Report

*This report is the outcome of a review meeting of environmental specialists and epidemiologists, held at Engelberg, Switzerland, July 1–4, 1985, and sponsored by The World Bank / United Nations Development Programme (UNDP) / World Health Organization (WHO) / International Reference Centre for Waste Disposal (IRCWD).*

## Synopsis; The Engelberg Statement

During July 1–4, 1985, a group of engineers, epidemiologists, and social scientists met in Engelberg, Switzerland, to discuss the health aspects of excreta and wastewater use in agriculture and aquaculture. The meeting was convened by The World Bank and the World Health Organization (WHO) and was hosted by the International Reference Centre for Waste Disposal (IRCWD). A list of participants is to be found at the end of this report.

The meeting considered comprehensive and critical literature reviews on the epidemiological, microbiological, sociological, and technical aspects of excreta and wastewater use in agriculture and aquaculture which have been commissioned by the World Bank/United Nations Development Programme (UNDP), WHO/United Nations Environment Programme (UNEP) and IRCWD. Based on these reviews (Shuval et al., 1985; Blum and Feachem, 1985; and Cross and Strauss, 1985) the meeting formulated a model of the health risks associated with the use of untreated excreta and wastewater in agriculture and aquaculture. This model suggests that the amount of excess infection and disease caused by various classes of pathogens is in the following order of descending magnitude: intestinal nematode infections (*Ascaris, Trichuris,* and the hookworms), excreted bacterial infections (bacterial diarrhoeas and typhoid), and excreted viral infections (including rotavirus diarrhoea and hepatitis A). In certain situations, there may also be a high excess of infection with trematodes and cestodes (particularly schistosomiasis, clonorchiasis and taeniasis). It was unanimously agreed that this model and the detailed epidemiological and microbiological data from which it is derived, provide a sufficient basis for the formulation of firm operational guidelines on the public health aspects of excreta and wastewater use.

Of the various methods available for minimizing health risks of excreta and wastewater use, highest priority was given to appropriate treatment of excreta and excreta-derived wastes (EDW)* prior to their application to fields or ponds. The meeting concluded that current guidelines and standards for human waste use are overly conservative and unduly restrict appropriate project development thereby encouraging unregulated human waste use.

The first quality criterion for both excreta and wastewater use in agriculture is the complete, or almost complete removal of the eggs of intestinal nematodes (to a geometric mean of $\leq 1$ viable nematode egg per litre). A major reduction (to a geometric mean of $\leq 10^3$ faecal coliforms per 100 ml) in the concentration of excreted bacteria is recommended for unrestricted use of wastewater in agriculture. If these standards are met, other pathogens such as trematode eggs and protozoal cysts are also reduced to undetectable levels. To achieve this degree of treatment of nightsoil or sludge, prolonged storage (> 6 months) or a shorter period of storage at an elevated temperature is required. For wastewater, the required degree of purification is assured by a waste stabilization pond system of 4–5 cells and an overall retention time of 20 days. For excreta and wastewater use in aquaculture, it is possible that less stringent standards are acceptable.

The model not only provides a basis for operational guidelines to be used immediately by project planners and policy makers, but also highlights areas of uncertainty and associated research priorities. Of greatest importance are selected epidemiological studies to be conducted both at sites where the new guidelines are being followed and the expected excess morbidity is zero, and at sites where the guidelines are not being followed and a detectable excess of certain diseases is expected.

The need for further research should not detract from the importance of giving professionals who are working in this area today, the best possible advice, including specific guidelines concerning the health aspects of excreta and wastewater use. Excreta and wastewater use in agriculture and aquaculture will become an increasingly common and important form of water resource conservation, waste disposal, water pollution control, and food production in many parts of the world over the next two decades. Policy and practice will need to be periodically revised in the light of new epidemiological evidence and the availability of new sanitary and agricultural technologies.

## 1. Aims of Review Meeting

The World Health Organization, the World Bank, UNDP and IRCWD, being involved in projects and programmes concerning the health aspects of wastewater and excreta use in agriculture and aquaculture, have sponsored major reviews to re-evaluate the state-of-the-art of this subject (Shuval et al., 1985; Blum and Feachem, 1985; and Cross and Strauss, 1985). To avoid overlapping, the groups of scientists carrying out these studies coordinated their activities through a series of consultations during the course of their work. It was agreed by the agencies involved that the draft reports would be reviewed during a joint meeting to attain the highest degree of coordination and consensus on all matters of health policy and technology to be included in the final reports. The aim was to ensure that these international development agencies working in this field develop a carefully coordinated, authoritative policy which could be effective and widely adopted throughout the world. The Engelberg meeting, hosted by IRCWD, was

* EDW includes wastewater, wastewater sludge, septage, latrine contents, nightsoil and composted excreta.

called together for this purpose. The meeting also reviewed a draft outlined for the proposed WHO/UNEP Series of Manuals on The Engineering and Managerial Aspects of Wastewater and Excreta Use in Agriculture and Aquaculture.

## 2. Revision of Current International Recommendations on Effluent Reuse

The meeting reviewed the progress that had been made in understanding the health effects of human waste reuse since the publication of the World Health Organization's widely accepted report on the subject published in 1973 and entitled "Reuse of Effluents: Methods of Wastewater Treatment and Health Safeguards" – WHO Technical Report Series No. 517, (1973). The report was based on the best knowledge and judgement available some 15 years ago. Since that time, a major effort has been made to review, update and reanalyse the available research findings, as well as new research that has come to light since that time. The new reports reviewed by the meeting have developed a revised approach to the nature of the health risks associated with human wastes reuse, thereby indicating that some of the earlier conventionally accepted approaches require a fundamental revision.

The authors of these reports have reached a consensus based on their evaluation of credible epidemiologic evidence, rather than mainly on the basis of survival of pathogens in human wastes, in soil and on crops. Their basic conclusions, endorsed unanimously by this meeting, indicate that many standards for human waste reuse, including those recommended in WHO Technical Report No. 517 are unjustifiably restrictive and not supported by currently available epidemiologic evidence.

Another important development which has taken place during the past 15 years has been the refinement of the rational basis for designing waste stabilization ponds so as to achieve highly effective levels of pathogen removal as a pretreatment for wastewater use in agricultural irrigation. There have also been many other major initiatives, particularly in wastewater reuse in developing countries, which call for updated guidelines in health and development policy.

Thus, the meeting recommended that WHO initiate revision of its Technical Report No. 517 in the nearest possible future. It is recommended that other interested international agencies such as The World Bank, FAO and UNEP participate in this revision or be otherwise consulted in an appropriate manner.

The meeting emphasized that the updated document which will replace WHO Technical Report Series No. 517 should also be published in the Technical Report Series so as to ensure its authoritative status.

## 3. The Epidemiological Approach

The reviews sponsored by the World Bank, UNDP, WHO, and IRCWD, referred to in section 1, have rejected the previous conventionally accepted view that health risks from wastewater or excreta use could be imputed from data on pathogen survival in wastewater, excreta and soil or on crops. Instead, they base their approach on an analysis of credible epidemiological studies showing demonstrable health effects from wastewater or excreta use. They also base their conclusions on theoretical considerations of those factors that influence the potential of various pathogens likely to be transmitted by wastewater and excreta use. From these reviews and analyses, a tentative model was developed of the health risks associated with the use of **untreated** wastewater and excreta. The likely amount of excess infecton or disease caused by different classes of pathogens, as predicted by this model, is compared in Table 1. The high excess of intestinal nematode infections predicted by the model is relatively well-founded and derives from several studies in both developed and developing countries. In contrast, the relatively lower excess of bacterial and viral infections is less well-founded. This is due to a paucity of epidemiologic evidence, although it is supported by the logic of the model based on theoretical considerations of potential risk.

Table 1:
**Relative Health Risks from Use of Untreated Excreta and Wastewater in Agriculture and Aquaculture**

| Class of pathogen | Relative amount of excess frequency of infection or disease |
|---|---|
| 1. Intestinal nematodes:<br>*Ascaris*<br>*Trichuris*<br>*Ancylostoma*<br>*Necator* | High |
| 2. Bacterial infections:<br>bacterial diarrhoeas (e.g. cholera)<br>typhoid | Lower |
| 3. Viral infections:<br>viral diarrhoeas<br>hepatitis A | Least |
| 4. Trematode and cestode infections:<br>schistosomiasis<br>clonorchiasis<br>taeniasis | From high to nil, depending upon the particular excreta use practice and local circumstances |

The model compares excess incidence but does not presently address either excess morbidity or excess mortality. It is possible that a disease having less excess frequency than another disease might, nonetheless, have greater excess disability or mortality and therefore be of greater public health concern.

Despite the uncertainties attached to parts of the model, it was agreed that it nevertheless provides a basis for firm operational guidelines on the minimization of the health risks associated with excreta use in agriculture and aquaculture. In particular, the model provides a basis for the revision of the current international guidelines on wastewater treatment and wastewater quality in wastewater irrigation projects as detailed in WHO Technical Report No. 517, 1973.

The meeting agreed that based on this revised analysis of the health risks associated with human waste reuse, some basic concepts and standards relating to this area are overly conservative and in need of revision. It was agreed that unduly restrictive standards on human waste reuse, which are not justified on health grounds, can lead to situations where unregulated reuse projects become tacitly accepted even when they actually pose real health risks.

## 4. Social and Behavioural Aspects

The meeting recognised that the successful use of excreta and wastewater in agriculture and aquaculture depends on many factors, such as for example institutional arrangements and financial and economic feasibility – subjects which were not within the scope of this meeting. However, the participants felt that a discussion should be included in this report of social and behavioural aspects, one all too often neglected area, which is of fundamental importance in the design and implementation of reuse schemes.

The meeting recognised that social and behavioural factors are of fundamental importance to health considerations in human waste utilization in three aspects:

(i) Human behaviour is a basic determinant factor in disease transmission from infected excreta.

(ii) Prophylactic or risk behaviours are controlled by deep-rooted cultural factors which differ from society to society, and which are to be taken into account at the planning stage of any excreta or wastewater reuse programme.

(iii) The social acceptability of innovations and improvements in human waste utilization technologies may seriously affect their successful implementation.

The literature review presented at the meeting (Cross and Strauss, 1985) indicates that little relevant research on these aspects has been undertaken, and the meeting recognised the importance of developing this neglected area.

The meeting also recognised that in many instances it would be highly desirable to seek the advice of social scientists in the development of excreta and wastewater reuse programmes, and in the design of epidemiological studies which incorporate behavioural aspects. Proposals for further research in this area are presented in section 8.

## 5. Guidelines for the Quality of Treated Wastewaters for Agricultural Irrigation

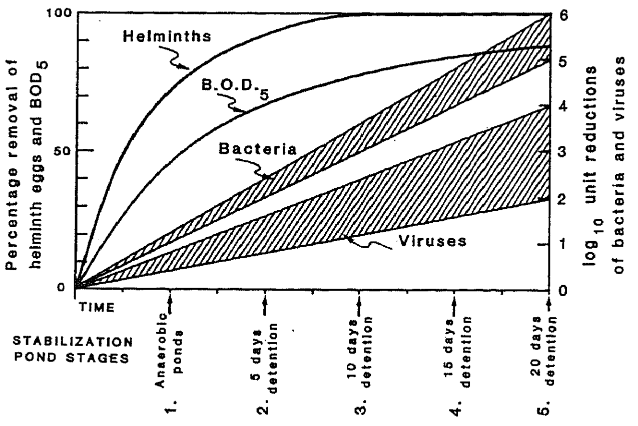
Table 2 contains the meeting's recommendations for the microbiological quality of treated wastewaters to be used for agricultural irrigation. These recommendations are technically feasible and in accord with the best currently available epidemiologic evidence (Shuval et al., 1985; Blum and Feachem, 1985). They introduce for the first time a guideline for the helminthic quality of treated wastewater. This is intentionally innovative, however, many details have yet to be finalised concerning standardization of sampling frequency and laboratory techniques for egg enumeration and viability assessment (section 8). The quality guideline for restricted irrigation (trees, industrial and fodder crops, fruits trees, and pasture) implies a high removal (> 99 percent) of helminth eggs, and its purpose is to protect the health of agricultural labourers. It can be readily achieved through a variety of treatment technologies but, in many cases, the most appropriate treatment method will be a two-cell waste stabilization pond system (either a 1-day anaerobic pond followed by a 5-day facultative pond, or two 5-day facultative ponds).

The guidelines for unrestricted irrigation (edible crops, sports fields and public parks) comprise the same requirement for helminth eggs and a maximum geometric mean concentration of 1000 faecal coliforms per 100 ml. The latter recommendation implies a very high level of removal of faecal bacteria (5–6 $\log_{10}$ units or > 99.999 percent). Its purpose is to protect the health of the consumers of crops (principally vegetables). This is readily achievable in a properly designed series of waste stabilization ponds. For the range of temperatures normally encountered in tropical and subtropical areas, a series of four 5-day ponds will normally produce an effluent of this required quality (Figure 1). Such a series of ponds will also produce a stable and aesthetically acceptable effluent. The irrigation of sports fields and public parks, especially hotel lawns, may require a more stringent standard as the health risks may be greater to those who come into contact with recently irrigated grass.

## 6. Appropriate Wastewater Treatment Methods

The meeting reaffirmed that in tropical and subtropical countries, the most appropriate wastewater treatment technology is generally waste stabilization ponds. As noted above, this process is well able to produce an effluent which meets the recommended microbiological quality guidelines for unrestricted irrigation, both at low cost and with minimal operational and maintenance requirements; indeed they can be easily designed to produce effluents of even higher qualities. However, because of the extensive land requirement of ponds, the meeting recommended that priority be given to the development of alternative low-cost treatment processes which require less land but are still capable of producing effluents which meet the recommended microbiological quality guidelines (section 5).

Fig. 1:
**Generalized Removal Curves for BOD, Helminth Eggs, Excreted Bacteria and Viruses in Waste Stabilization Ponds at Temperatures Above 20 °C. (after Shuval et al., 1985).**




## 7. Appropriate Quality Guidelines and Treatment of Excreta

### *1) Agricultural use*

A fundamental distinction has to be made as regards the application of excreta (and excreta-derived products such as compost and latrine contents) to the fields before and after the start of the crop growing cycle. When applied **before** the start of the growing cycle, no pathogen quality guidelines are required if (a) the wastes are deposited on the field in trenches and covered, (b) farm workers are adequately protected from contamination during handling of the waste material, and (c) the crops are planted in between the trenches (Figure 2).

If the waste products are applied **after** the start of the crop growing cycle or if they are not in conformity with the recommendation in Figure 2, then they should comply with the quality guidelines for wastewater irrigation given in Table 2.

The recommended method for the treatment of liquid nightsoil (defined as faeces and urine, occasionally with the addition of small quantities of toilet flush water) when applied during the crop growing cycle, is storage for one week, after which the supernatant can be applied to the field. During this storage period, almost all the helminth eggs will settle, thereby posing little health risk to the farm workers who handle the supernatant. However, since the numbers of excreted bacteria and viruses will not be reduced to acceptable levels, the supernatant should only

Table 2:
**Tentative Microbiological Quality Guidelines for Treated Wastewater Reuse in Agricultural Irrigation (1)**

| Reuse process | Intestinal nematodes (2) (geometric mean no. of viable eggs per litre) | Faecal coliforms (geometric mean no. per 100 ml) |
|---|---|---|
| **Restricted irrigation** (3) | | |
| Irrigation of trees, industrial crops, fodder crops, fruit trees (4) and pasture (5) | ≤1 | not applicable (3) |
| **Unrestricted irrigation** | | |
| Irrigation of edible crops, sports fields, and public parks (6) | ≤1 | ≤1000 (7) |

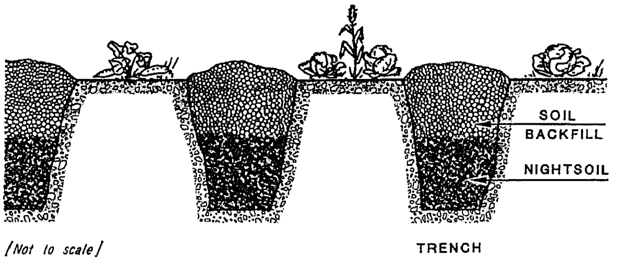
(1) In specific cases, local epidemiological, socio-cultural, and hydrogeological factors should be taken into account, and these guidelines modified accordingly.
(2) *Ascaris, Trichuris* and hookworms.
(3) A minimum degree of treatment equivalent to at least a 1-day anaerobic pond followed by a 5-day facultative pond or its equivalent is required in all cases.
(4) Irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground.
(5) Irrigation should cease two weeks before animals are allowed to graze.
(6) Local epidemiological factors may require a more stringent standard for public lawns, especially hotel lawns in tourist areas.
(7) When edible crops are always consumed well-cooked, this recommendation may be less stringent.

be used for restricted irrigation. The one-week storage time can be readily assured if three storage tanks are available and used in a controlled sequence (one being filled, one undergoing quiescent settling, and one in use). The sludge that settles to the bottom of the tank is likely to be very rich in helminth eggs and should be considered in the same way as septage (see below). As none of this sludge is to be applied directly to the field, simple methods to ensure this should be incorporated in the design of the storage tanks.

Other forms of excreta (such as septage, sludge from biogas digesters, and the contents of single-pit latrines) cannot be treated by the above method since they do not allow for settling of helminth eggs, and must therefore either be treated by other methods or not applied to the field during the crop growing cycle. Appropriate treatment methods include aerobic thermophilic composting and prolonged storage (>6 months). Both these processes can produce, if properly operated, a product free from almost all pathogens although very few helminth eggs may still be present. The contents of correctly used alternating twin-pit latrine systems do not require further treatment as they are essentially pathogen-free. In contrast, the contents of composting latrines are generally not pathogen-free and must thus be treated as above.

The meeting did not consider the use of sludge from municipal and industrial wastewater treatment plants, as there is a large literature on pathogen survival and toxic chemicals in such sludges. it was, however, noted that the proposed WHO/UNEP Manual series would contain guidelines for the use of this material in tropical and subtropical agriculture.

Fig. 2:
**Recommendation for Crop Planting Between Nightsoil Trenches to Avoid Crop Contamination**




*2) Aquacultural use*

Appropriate treatment technologies for wastes used in aquaculture are harder to specify. Intestinal nematode eggs are not an important quality criterion but, in certain situations, trematode eggs will be. Trematode eggs, for instance those of ***Schistosoma, Fasciolopsis*** and ***Clonorchis,*** are relatively fragile compared to ***Ascaris*** eggs and can be eliminated in a shorter time period. The appropriate bacterial and viral quality requirements for wastewater and excreta to be used for aquaculture depend to a great extent on the methods of fish and water plant harvesting, marketing and cooking. Simple storage of excreta for 7 days will ensure the destruction of all *Clonorchis* eggs (relevant in fish farming), but will not remove those of ***Fasciolopsis*** (relevant in water plant culture) and ***Schistosoma*** (relevant to occupational health in all aquacultural practices), which are both able to survive for periods of a few weeks. Further research on simple excreta treatment methods and other control strategies is required before any quality guidelines can be proposed for either trematode eggs, bacteria or viruses.

## 8. Research Priorities

The meeting identified several priority areas for applied research into certain epidemiological, microbiological, sociological and technical aspects of human waste use in agriculture and aquaculture. Although the potential areas of research are outlined in some detail in this report, the meeting emphasizes that this should not be construed as a justification for inaction in carrying out the applied recommendations. These practical recommendations are based on the best currently available scientific evidence and judgement on this subject.

The suggested areas of research are:

### A. Epidemiological studies

Epidemiological research in the field of excreta and wastewater use has three important functions: (1) to guide technical policy decisions towards the most cost-effective excreta treatment options in given settings; (2) to fill important gaps in our knowledge of the health risks of excreta use; and (3) to improve and refine the epidemiologic methods likely to be of most use in the context of excreta and wastewater use. These issues are discussed in turn.

(1) Guiding technical policy

The tentative wastewater quality guidelines given in Table 2 reflect best judgements based on the epidemiological data to date (mainly on intestinal nematode health risks), as well as reasonable assumptions extrapolated from considerations of potential risk. It is highly desirable that the validity of these standards be confirmed by further epidemiological studies, and modified as necessary. Two categories of such epidemiological studies were identified:

(a) Category I studies in which the health risks associated with the application of excreta and wastewaters meeting the guideline standards are examined — here the expected outcome is that there will be no excess risk. The results of such studies would either confirm the validity of the guidelines or indicate the need for greater stringency.

(b) Category II studies in which the health risks associated with the application of excreta or wastewaters not meeting the guideline standards are examined — here the expected outcome is that there will be an excess risk. These studies are important for 3 reasons: (i) to test the ability of the epidemiological method used to detect expected risks (and hence lend more credibility to the results of the Category I studies); (ii) to explore whether contravening the guidelines does carry health risks; (iii) and to promote appropriate remedial action where risks are identified. A sufficient number of such studies may identify a threshold level of excreta and wastewater quality as well as health risks which might indicate whether a relaxation of the recommended quality guidelines is warranted.

(2) Filling gaps in knowledge

A number of priority areas for further research were identified in the following areas:

(a) ***Health risk.*** Those health problems for which most morbidity is expected from excreta or wastewater use or for which there is as yet no data, were highlighted as priority areas of research. These problems include symptomatic diarrhoea, and aetiology-specific enteric infections, including intestinal nematode infections (particularly ***Ascaris, Trichuris,*** and the hookworms), typhoid fever, rotavirus diarrhoea, and infectious hepatitis. In some situations an examination of the risk of cholera, taeniasis and trematode infections would be a priority.

(b) ***At risk group.*** In terms of total morbidity, the health risk to consumers of wastewater-irrigated or excreta-fertilized crops and consumers of fish grown in excreta-fertilized ponds should receive the highest priority. It is recognized that the consumer exposure group may be difficult to identify, and that in rural areas it may not be possible to distinguish between occupational and consumer exposure. However, efforts should be made to identify situations where the consumer exposure group can be determined accurately. In some settings, the health risk to workers may be a priority area of study.

(c) ***Type of waste and method of application.*** Studies should be carried out to examine the health risk associated with each of the major types of waste available for use – wastewater effluent, excreta and the various excreta-derived products. Those methods of application with the highest predicted risk should receive priority.

(d) ***Level of hygiene.*** Very little is known about how risk may vary with the level of personal and domestic hygiene. Studies should be carried out in a variety of different hygiene settings.

(3) Refining epidemiological methods

There are a number of epidemiological methods which might be applied to the measurement of the health risks of excreta and wastewater use. Previous studies have been plagued by a number of methodological problems. The choice of the most appropriate epidemiological method in a given setting will depend on available resources (manpower, expertise, logistics, laboratory facilities, funds, and time) and the health indicator chosen for study. Clear attempts should be made to improve on past efforts and to focus on the use of methods which can provide good quality data in limited time and at low cost.

**B. Pathogen survival studies**

It was decided that further research was needed on the microbial content of excreta and treated wastewaters to allow further validation of such treatments under a variety of different field conditions. Ideally, such studies should be carried out in countries where agricultural or aquacultural reuse is practised, or where such reuse is anticipated. The aim of these studies would be to test the performance of a variety of treatment options to achieve the quality guidelines given in Table 2, and thus to find the minimum level of treatment required to meet these standards.

It is recommended that the main treatment processes to be studied are the ones known to be the most efficient at removing pathogens in areas where human waste is reused; as noted in section 6 this includes waste stabilization ponds. In addition, the performance of other candidate systems and suboptimal systems in use in the field should be evaluated. Considering wastewater treatment, this would include for example:

(a) pond systems operating under suboptimal conditions (for example: fewer cells, < 5-day retention);
(b) pond systems modified to include land saving options (for example: aeration, increased depth); and
(c) pond systems which were properly designed and operating at their design load – this study would investigate the removal kinetics of excreted pathogens about which there is currently insufficient knowledge.

In the area of excreta treatment, the product of a variety of different treatment options should be studied, including those in which storage time alone and those in which a combination of storage time and elevated temperature form the basis of treatment.
These should include for example:

(a) alternating twin-pit latrines;
(b) collective storage of nightsoil; and
(c) municipal aerobic thermophilic composting systems operating at different levels of efficiency.

It was considered that the study of the survival of intestinal nematode eggs was the first priority, followed by the survival of excreted bacteria. While the study of the survival of viruses was considered of lesser priority for the time being, it was felt that when good techniques for the isolation of rotavirus from waste become available, the monitoring of rotavirus should become a priority. In addition, it was strongly recommended that obtaining good quality data on the concentration of microorganisms in human wastes used in agriculture and aquaculture should be an integral part of the epidemiological studies recommended above.

Standardized techniques have been available for the determination of the concentration of faecal coliforms for a long time. Since a helminthic quality guideline is now being recommended, it was felt that it is imperative to develop as soon as possible a simple standardized test to quantity the concentration of viable eggs in all types of treated excreta and wastewaters. In addition, attention should be paid to the mode of expression of this guideline – whether it should refer to mean concentration (arithmetic or geometric) or a concentration to be obtained in a specified number of samples taken at a specified frequency. Following these investigations, a manual should be prepared stating in detail the standardized method and the mode of expression of the results.

### C. Social aspects

Future social research applied to human waste reuse projects was discussed according to the principal areas of concern identified in section 4:

(i) *Behavioural aspects of disease transmission*

The literature review (Cross and Strauss, 1985) reveals that there is a need for further detailed up-to-date ethnographic studies on existing practices and beliefs with regard to all aspects of human waste reuse. These studies should reflect a variety of cultural settings and be related to different waste reuse techniques. Initial descriptive studies are needed in order to develop precise definitions of possible confounding or risk factors for consideration in the design of epidemiological studies, and to enhance knowledge of prophylactic behaviours. The meeting proposed close collaboration between epidemiologists and social scientists in research on behavioural aspects of disease transmission. Following the determination of behavioural risk factors in social and epidemiological studies, proposals for behaviour modification as a control measure to minimize infection risk from waste utilization, should be developed.

(ii) *Social acceptability of waste utilization innovation or improvements*

Participants at the meeting felt that the social acceptability of human waste reuse innovations and improvements was of serious concern for the future development and implementation of human waste reuse programmes. The group recommended that appropriate social feasibility studies be included where demonstration projects are being considered, alongside other feasibility studies (for example: economic, institutional) as necessary. Technical innovations identified as requiring further investigation of their social acceptability include the following:

(a) wastewater use,
(b) the triple tank storage system for liquid nightsoil (see section 5), and
(c) aerobic thermophilic co-composting systems.

### D. Research on wastewater and excreta treatment

(a) There is a need for some further evaluation of existing low cost wastewater technologies in light of the specific pathogen removal priorities identified by the meeting (see B above).

(b) While stabilization ponds have been extensively studied and are known to be effective for helminth and bacterial removal, there is an urgent need to evaluate the efficiency of land saving systems such as deep (>3 m) facultative and maturation ponds and aerated lagoons of various designs which can be used whenever conventional pond systems cannot be constructed (due, for example, to high land costs, adverse topography or scarcity of agricultural land). Helminth removal efficiencies of such systems have not been studied to date.

(c) Assuming that intensively aerated lagoons will only achieve limited helminth removal, there is a need to develop and evaluate additional specific helminth removal wastewater treatment technologies which could be used as a second stage to aerated lagoons. Examples of possible technologies which should be evaluated include:

(i) filtration
(ii) microstraining
(iii) chemical coagulation
(iv) ovicidal disinfection

(d) In addition there is a need to develop and evaluate intermediate technologies which may be used as interim or palliative measures to upgrade existing situations of uncontrolled wastewater reuse which pose severe health risks. Particular emphasis should be placed on determining optimal design configurations and minimal detention times required for effective helminth removal in first stage anaerobic ponds or similar systems of relatively short detention times.

(e) Development of simple mechanical systems for desludging anaerobic ponds to eliminate the need to interrupt operation, (for example, portable sludge pumps).

(f) Study the design criteria and pathogen removal efficiency of lagoon systems designed primarily for the treatment of septage and nightsoil.

## 9. Demonstration Projects

Demonstration projects for the various treatment and reuse technologies should be implemented to adapt the technologies and practices to specific country conditions. While doing this, appropriate key variables should be monitored in order to provide local information on these processes that may lead to future design and operational improvements.

## 10. The Need for Dissemination of Information and Follow-Up

The meeting recommended that the international agencies concerned with the promotion and evaluation of wastewater and excreta use in agriculture and aquaculture develop programmes to promote the dissemination of the scientific and technical information about various waste reuse options, and actively promote reuse options in future development projects. A further point emphasized by the meeting was the need to develop mechanisms to promote the research recommendations of the meeting and to monitor and evaluate the research outputs.

The meeting emphasized that since wastewater and excreta use projects will probably be expanding rapidly in the future, mechanisms of coordination should be established to evaluate and review the progress made in this field. This will provide independent feedback to the international agencies involved. One way of achieving this objective would be for the IRCWD to establish a working group on Wastewater and Excreta Use which would convene on a regular (possibly annual) basis.

## 11. References

**Blum, D., Feachem, R.** (1985) *Health aspects of nightsoil and sludge use in agriculture and aquaculture: An epidemiological perspective,* International Reference Centre for Waste Disposal, Duebendorf, Switzerland.

**Cross, P., Strauss, M.** (1985) *Utilization of excreta in agriculture and aquaculture. Part I: Existing practices and beliefs. Part II: Pathogen survival,* International Reference Centre for Waste Disposal, Duebendorf, Switzerland.

**Shuval, H.I., Adin, A., Fattal, B., Rawitz, E., & Yekutiel, P.** (1985) *Health effects of wastewater reuse in agriculture,* World Bank Studies in Water Supply and Sanitation, The World Bank, Washington, D.C.

**World Health Organization,** Technical Report Series No. 517 (1973) *Reuse of effluents: Methods of wastewater treatment and health safeguards,* Report of a WHO Meeting of Experts, Geneva.

## 12. List of Participants

Dr Deborah BLUM — Lecturer in Communicable Disease Epidemiology, Dept. of Tropical Hygiene, London School of Hygiene & Tropical Medicine, Keppel Street, London WC1E 7HT/U.K.

Ms Ursula BLUMENTHAL — Research Fellow, Dept. of Tropical Hygiene, London School of Hygiene & Tropical Medicine, Keppel Street, London WC1E 7HT/U.K.

Mr Piers CROSS — Social Anthropologist – IRCWD Consultant, Eval. & Plan. Centre, London School of Hygiene & Tropical Medicine, Keppel Street, London WC1E 7HT/U.K.

Dr László DAVID — Senior Programme Officer, United Nations Env. Prog. UNEP, P.O. Box 30552, Nairobi/Kenya

Dr Richard G. FEACHEM (Chairman) (alternating) — Head, Dept. of Tropical Hygiene, London School of Hygiene & Tropical Medicine, Keppel Street, London WC1E 7HT/U.K.

Mr Charles G. GUNNERSON — Consulting Env. Engineer, 205 Pawne Drive, Boulder, Colorado 80303/USA

Mr John M. KALBERMATTEN — Consultant Sanitary Eng., 3630 Garfield St. N.W., Washington, D.C. 20007/USA

Dr D. Duncan MARA (Rapporteur) — Professor of Civil Eng., University of Leeds, Leeds LS2 9JT/U.K.

Dr Letitia A. OBENG — Project Officer, Applied Technology Unit, Water and Urban Dept. N832, World Bank, 1818 H St., NW., Washington, D.C. 20433/USA

Ms Sylvie PETER (Editor) — Translator, IRCWD, International Reference Centre for Waste Disposal, Ueberlandstrasse 133, CH-8600 Duebendorf/Switzerland

Mr Alex REDEKOPP — Senior Program Officer, Water Supply & Sanitation, Health Sciences Div., International Dev. Research Centre IDRC, P.O. Box 8500, Ottawa/Canada K1G 3H9

Mr Gunnar SCHULTZBERG — Sanitary Engineer, Community Water Supply & Sanitation (CWS), Env. Health Div. (EHE), World Health Organization, 1211 Geneva 27/Switzerland

Prof. Hillel I. SHUVAL (Rapporteur) — Director, Env. Health Lab., School of Public Health & Community Medicine, Hebrew University – Hadassah Faculty of Medicine, Jerusalem/Israel and Consultant to World Bank

Mr Martin STRAUSS — Sanitary Engineer, IRCWD, International Reference Centre for Waste Disposal, Ueberlandstrasse 133, CH-8600 Duebendorf/Switzerland

Dr Daniel TARANTOLA — Epidemiologist, Dev. of Epidemiological & Health Statistical Services, World Health Organization, Avenue Appia, 1211 Geneva 27/Switzerland

Mr Alain THYS (Chairman) (alternating) — Chief Water Supply & Sewerage Div., Regional Office for Latin America & Caribbean, World Bank, 1818 H St., NW., Washington, D.C. 20433/USA

Mr Gerhard TSCHANNERL — Senior Project Officer, Applied Technology Unit, Water Supply & Urban Dev. Dept., World Bank, 1818 H St., NW., Washington, D.C. 20433/USA

Prof. Perez YEKUTIEL — Consultant Epidemiologist, Env. Health Lab., School of Public Health, Hebrew University, Hadassah Faculty of Medicine, Jerusalem/Israel

Dr Vincent ZAYER — Senior Project Manager, Economics & Dev. Plan. Div., Motor Columbus Consulting Engineers Inc., Parkstrasse 27, CH-5401 Baden/Switzerland

S. Peter, Editor
"IRCWD News"
Swiss Federal Institute for Water Resources and Water
Pollution Control (EAWAG)
Ueberlandstrasse 133, CH-8600 Duebendorf, Switzerland