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), United Nations Environment Programme (UNEP), and 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, and sociological 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, and sociological aspects of excreta and wastewater use in agriculture and aquaculture. The model does not only provide a basis for operational guidelines to be used immediately by project planners and policymakers, 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 at 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 more common and important 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 (Shuvval 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
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 wastewater since the publication of the World Health Organization's widely accepted report on the subject published in 1973 and entitled "Re-use 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 judgment 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 to bring 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 pre-treatment 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 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 inferred 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 infection or disease caused by different classes of pathogens, as predicted by this model, is compared in Table 1.

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

<table>
<thead>
<tr>
<th>Class of pathogen</th>
<th>Relative amount of excess frequency of infection or disease</th>
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<tr>
<td>1. Intestinal nematodes:</td>
<td>High</td>
</tr>
<tr>
<td>Ascaris</td>
<td></td>
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<tr>
<td>Trichuris</td>
<td></td>
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<tr>
<td>Ankylostoma</td>
<td></td>
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<tr>
<td>Necator</td>
<td></td>
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<tr>
<td>2. Bacterial infections:</td>
<td>Lower</td>
</tr>
<tr>
<td>bacterial diarrhoea</td>
<td></td>
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<tr>
<td>(e.g. cholera)</td>
<td></td>
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<tr>
<td>typhoid</td>
<td></td>
</tr>
<tr>
<td>3. Viral infections:</td>
<td>Least</td>
</tr>
<tr>
<td>viral diarrhoeas</td>
<td></td>
</tr>
<tr>
<td>hepatitis A</td>
<td></td>
</tr>
<tr>
<td>4. Protozoal and cestode infections:</td>
<td></td>
</tr>
<tr>
<td>schistosomiasis</td>
<td>from high to nil depending upon the particular excreta use practice and local circumstances</td>
</tr>
<tr>
<td>echinococcosis</td>
<td></td>
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<tr>
<td>toxocariasis</td>
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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 aqua-
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 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 may seriously affect their successful implementation.

The literature review presented at the meeting (Gross and Strauss, 1986) 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 (Shuvay et al., 1986; Blum and Paachem, 1987). 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 B). The quality guideline for restricted irrigation (trees, industrial and fodder crops, fruits, trees, and pastures) 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 (5e6 log10 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 6-day ponds will normally produce an effluent of the 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).
7. Appropriate Quality Guidelines and Treatment of Excreta

I. Agricultural use

A fundamental distinction has to be made as regards the application of excreta (and excreta-derived products such as compost and litter 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 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 livestock (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

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Table 2:

<table>
<thead>
<tr>
<th>Reuse process</th>
<th>Intestinal nematodes (2) (geometric mean no. of viable eggs per litre)</th>
<th>Fecal coliforms (geometric mean no. per 100 ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricted irrigation (3)</td>
<td>1</td>
<td>not applicable (3)</td>
</tr>
</tbody>
</table>

Irrigation of trees, industrial crops, fodder crops, fruit trees (4) and pasture (5)

Unrestricted irrigation

Irrigation of edible crops, sports fields, and public parks (6)

≤ 1

≤ 1000 (7)

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(1) In specific cases, local epidemiological, sociocultural, 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 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 sub-tropical agriculture.

![Fig. 2](image)

**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 sewage to be used for aquaculture depend on the extent of 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 action in carrying out the planned 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 epidemiological 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: (a) to test the ability of the epidemiological method used to detect expected
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 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 wastewater 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 hours, < 1.5 day retention);
(b) pond systems modified to include land savings options (for example: aeration, increased depth);
(c) pond systems which were properly designed and operating at their design load — this study would investigate the removal kinetics of excretal 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 forms the basis of treatment. These should include for example:

(a) alternating twin-pit latrines;
(b) collective storage of night soil; 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 water 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 an appropriate, simple, standardised test to quantify the concentration of viable eggs in all types of treated excreta and wastewaters. In addition, attention should be paid to the choice of expression of the 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 principles of research identified in section 4.

(i) Behavioral 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 diversity 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 behaviors. The meeting proposed close collaboration between epidemiologists and social scientists in research on behavioral aspects of disease transmission. Following the determination of behavioral risk factors in social and epidemiological studies, proposals for behavior 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 thermophobic co-composting systems.

7. Research on wastewater and excreta treatment

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 lagoon. Examples of possible technologies which should be evaluated include:

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

(d) In addition, there is a need to develop and install intermediate technologies which may be useful in interim or palliative measures to upgrade waste treatment situations of uncontrolled wastewater reuse where 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 pond-type similar systems of relatively short detention times.

(e) Development of simple mechanical systems for (i) studying 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 wastewater and sewage treatment 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 processing 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 wastewater options, and actively promote research and 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 (RCW) to establish a working group on Wastewater and Excreta Use which would convene on a regular (possibly annual) basis.
11. References


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