Guidelines for the safe use of wastewater and excreta in agriculture and aquaculture:

Measures for public health protection

Executive Summary

Introduction

The overall objective of these Guidelines is to encourage the safe use of wastewater and excreta in agriculture and aquaculture in a manner that protects the health of the workers involved and of the public at large. In this context "wastewater" refers to domestic sewage and municipal wastewaters that do not contain substantial quantities of industrial effluent; "excreta refers to nightsoil and to excreta-derived products such as sludge and septage. Health protection considerations will generally require that some treatment be applied to these wastes to remove pathogenic organisms. Other health protection measures are also considered, including crop restriction, waste application techniques and human exposure control.

The Guidelines are addressed primarily to senior professionals in the various sectors relevant to wastes reuse, and aim to prevent transmission of communicable diseases while optimizing resource conservation and waste recycling. Emphasis is therefore on control of microbiological contamination rather than on avoidance of the health hazards of chemical pollution, which is of only minor importance in the reuse of domestic wastes and is adequately covered in other publications. Purely agricultural aspects are considered only in so far as they are relevant to health protection.

Hygiene standards applied to wastes reuse in the past, based solely on potential pathogen survival, have been stricter than necessary. A meeting of sanitary engineers, epidemiologists and social scientists, convened by the World Health Organization, the World Bank and the International Reference Centre for Waste Disposal and held in Engelberg, Switzerland, in 1985, proposed a more realistic approach to the use of treated wastewater and excreta, based on the best and most recent epidemiological evidence. The recommendations of the resulting Engelberg Report have formed the basis for these Guidelines.

Scope

Sections 2 and 3 of the Guidelines review the history and benefits of wastes reuse and cite examples of existing practices in various parts of the world. Public health aspects, including the practical implications of recent epidemiological advances, are introduced in Section 4, and sociocultural factors are considered in Section 5. Section 6 discusses environmental protection and enhancement through wastes reuse. Feasible and appropriate control measures for public health protection are comprehensively reviewed in Section 7, and the institutional, legal and financial aspects of project pianning and implementation are discussed in Section 8.

Human wastes as a resource

Human wastes are a widely used resource in many parts of the world. The Guidelines concentrate on the following three practices, which are the most common:

- use of wastewater for crop irrigation;
- use of excreta for soil fertilization and soil structure improvement;
- use of wastewater and excreta in aquaculture.

Wastewater use in agriculture

In the past two decades there has been a notable increase in the use of wastewater for crop irrigation, especially in arid and seasonally arid areas of both industrialized and developing countries. This has occurred as a result of several factors:

- the increasing scarcity of alternative waters for irrigation, exacerbated by increasing urban demand for potable water supplies, and the growing recognition by water resource planners of the importance and value of wastewater reuse;
- the high cost of artificial fertilizers and the recognition of the value of nutrients in wastewater, which significantly increase crop yield;
- the demonstration that health risks and soil damage are minimal if the necessary precautions are taken;

- the high cost of advanced wastewater treatment plants; and
- the sociocultural acceptance of the practice.

Normal domestic and municipal wastewater is composed of 99% water and 0.1 0/0 suspended, colloidal and dissolved solids -organic and inorganic compounds, including macronutrients such as nitrogen, phosphorus and potassium as well as essential micronutrients. Industrial effluents may add toxic compounds, but not in detrimental quantities, and only the boron sensitivity of the crop being irrigated needs consideration. The application rate of wastewater is calculated in the same way as for freshwater irrigation, with due regard to evapotranspiration demand, leaching requirements and salinity and sodicity control.

Excreta use in agriculture

The ancient practice of applying human excreta to the land has maintained soil fertility in many countries of Eastern Asia and the Western Pacific for over 4000 years, and remains the only agricultural use option in areas without sewerage facilities. Most households in developing countries will continue to lack sewerage systems in the foreseeable future; emphasis should therefore be placed on establishing on-site sanitation systems that readily permit the safe use of stored excreta-for example, alternating twin-pit or pour-flush latrines and compost toilets.

Each person typically produces 1.8 litres of excreta daily; this comprises 350 grams of dry solids, including 90 grams of organic matter, 20 grams of nitrogen, plus other nutrients-mainly phosphorus and potassium. Excreta treatment not only destroys pathogenic microorganisms but also converts these nutrients to forms more readily usable by crops and stabilizes the organic matter, producing a better soil conditioner. Excreta and excreta-derived products are generally applied to the land before planting at annual rates of 5-30 tonnes per hectare (t/ha) (10 t/ha = 1 kg/m2).

Excreta and wastewater use in aquaculture

Aquaculture refers to the ancient practices of fish culture, notably of carp and tilapia, and the growing of aquatic crops, such as water spinach, water chestnut, water calthrop and lotus. Fertilization of aquaculture ponds with human and animal wastes has been practised for thousands of years in Asia; today at least two-thirds of the world yield of farmed fish comes from ponds fertilized in this way. China produces 60% of the world's farmed fish in only 27% of the world's area of fish-ponds; the mean annual yield from Chinese fish-ponds is 3200 kg/ha but well managed intensive polyculture ponds can produce up to 7000 kg/ha. Such fish represent the cheapest source of animal protein.

Fish can also be successfully farmed in the maturation ponds of a series of waste stabilization ponds: annual yields of up to 3000 kg/ha have been obtained. The sale of the harvested fish can be used to pay for improved operation and maintenance of municipal sewerage systems.

Examples of human waste reuse

Of the many examples of human wastes reuse, the few described in the Guidelines were chosen to represent a wide range of locations and sociocultural settings, scales of operation, treatment processes, application techniques and crops harvested. The examples given are:

Wastewater use in agriculture: Australia, Federal Republic of Germany, India, Mexico, Tunisia.

Excreta use in agriculture: China, Guatemala, India, United States of America.

Wastewater and excreta use in aquaculture: India, Indonesia.

Public health aspects

Health risks

Excreta-related diseases are very common in developing countries, and excreta and wastewater contain correspondingly high concentrations of excreted pathogens- bacteria, viruses, protozoa and helminths. About 30 such diseases are of public health importance, and many of these are of specific importance in waste reuse schemes. However, the agricultural or aquacultural use of excreta and wastewater can result in an *actual* risk to public health only if *all* of the following occur:

(a) *either* an infective dose of an excreted pathogen reaches a field or pond, or the pathogen multiplies in the field or pond to form an infective dose;

(b) the infective dose reaches a human host;

(c) the host becomes infected; and

(d) the infection causes disease or further transmission.

If(d) does not occur, then (a), (b) and (c) can pose only *potential* risks to public health. Moreover, if this sequence of events is broken at any point, the potential risks cannot combine to constitute an actual risk.

It is now possible to design and implement schemes for human wastes reuse that pose no risk to public health, but this requires an understanding of the epidemiology of the infections in relation to wastes reuse. In this way, adequate standards for the microbiological quality of excreta and wastewater intended for reuse can be established and public health properly protected.

Epidemiological evidence

The actual public health importance of excreta or wastewater reuse can be assessed only by an epidemiological study of the particular practice to determine whether it results in measurably greater incidence or prevalence of disease, or intensity of infection, than occurs in its absence. Such studies are methodologically difficult, and there have been only a few well designed epidemiological studies on human wastes reuse; more evidence is available about wastewater irrigation than about excreta use in agriculture or about aquacultural use.

Wastewater irrigation. A recent World Bank report (Technical Paper No. 51) reviewed all available epidemiological studies on wastewater irrigation and concluded that:

- Crop irrigation with untreated wastewater causes significant excess intestinal nematode infection in crop consumers and field workers. Field workers, especially those who work barefoot, are likely to have more intense infections, particularly with hookworms, than those not working in wastewater-irrigated fields.

- Irrigation with adequately treated wastewater does not lead to excess intestinal nematode infection in field workers or crop consumers.

- Cholera, and probably typhoid, can be effectively transmitted by irrigation of vegetable crops with untreated wastewater.

- Cattle grazing on pasture irrigated with raw wastewater may become infected with beef tapeworm, but there is little evidence of actual risks to humans.

- There is limited evidence that the health of people living near fields irrigated with raw wastewater is negatively affected, either directly by contact with the soil or indirectly by contact with farm workers. In communities with high standards of personal hygiene any negative effects are generally restricted to an excess incidence of benign, often viral, gastroenteritis, although there may also be an excess of bacterial infections.

- Sprinkler irrigation with treated wastewater may promote aerosol transmission of excreted viruses, but this is likely to be rare in practice because most people have normally high levels of immunity to endemic viral diseases.

It is clear that, when *untreated* wastewater is used to irrigate crops, there is a high actual health risk from intestinal nematodes and bacteria but little or no risk from viruses. Thus, treatment of wastewater is a highly effective method of safeguarding public health.

Excreta use in agriculture. A recent report (No. 05/85) published by the International Reference Centre for Waste Disposal reviewed epidemiological evidence on the agricultural use of excreta and concluded that:

- Crop fertilization with untreated excreta causes significant excess intestinal nematode infection in crop consumers and field workers.

- There is evidence that excreta treatment can reduce the transmission of nematode infection.

- Excreta fertilization of rice paddies may lead to excess schistosomiasis infection among rice farmers.

- Cattle may become infected with tapeworm but are unlikely to contract salmonellosis.

Aquacultural use. The IRCWD report also reviewed evidence for disease transmission associated with aquacultural use of excreta and wastewater; its findings were less conclusive than those concerning agricultural use because of the limited quantity and quality of available data.

Clear epidemiological evidence exists for the transmission of certain trematode diseases, principally those caused by *Clonorchis* (oriental liver fluke) and FuscioZopsis (giant intestinal fluke), but not for transmission of schistosomiasis (bilharzia), which is none the less a major potential risk to those who work in excreta-fertilized ponds. There was no conclusive evidence for bacterial disease transmission by passive transference of the pathogens by fish and aquatic vegetables, although this too remains a potential risk.

Microbiological quality criteria

Experts attending the First Project Meeting on the Safe Use of Human Wastes in Agriculture and Aquaculture, in Engelberg, Switzerland, in 1985, reviewed epidemiological evidence concerning the agricultural use of human wastes and formulated the Engelberg Guidelines for the microbiological quality of *treated* wastewater intended for crop irrigation. Those guidelines recommend that treated wastewater should contain:

- < 1 viable intestinal nematode egg per litre (on an arithmetic mean basis) for restricted or unrestricted irrigation; and

- < 1000 faecal coliform bacteria per 100 millilitres (on a geometric mean basis) for unrestricted irrigation.

Unrestricted irrigation refers to irrigation of trees, fodder and industrial crops, fruit trees and pasture, and restricted irrigation to irrigation of edible crops, sports fields and public parks.

The guidelines are also applicable to agricultural use if the excreta, in the form of liquid nightsoil for example, is applied to the field while crops are growing.

The intestinal nematode egg guideline value is designed to protect the health of both field workers and crop consumers and represents a high degree of egg removal from the wastewater (> 99%). The faecal coliform guideline value is less stringent than earlier recommendations, but is in accord with modern standards for bathing waters, for example, and more than adequate to protect the health of consumers. Effluents complying with both guideline values can be simply and

may persuade them to change include the greater efficiency of other irrigation methods and reduced mosquito nuisance. If the agricultural extension service is not able to promote hygienic application methods, the body controlling waste distribution may still be able to do so.

(d) Human exposure control

Measures to reduce exposure to diarrhoeal diseases generally and to promote good case management are well known components of primary health care. Obvious measures are provision of adequate water supplies and sanitation facilities. Care is required to ensure that the wastes do not contaminate nearby sources of drinking-water.

Where salaried field or pond workers are involved, employers' responsibilities are often set down in existing legislation on occupational health. Hygiene education is also needed for crop handlers and consumers; markets may be the ideal places for advising consumers on this subject.

Once the necessary precautions have been explained, local residents are best placed to ensure that their health is not jeopardized. A residents' health committee can be a focus for a health education campaign as well as monitoring the practice of wastes reuse.

Treatment of agricultural workers and their families for intestinal helminth infections is relatively easy to administer in a formal wastewater irrigation scheme, although additional health personnel may be required. Where wastewater is used on many small farms, the identification and treatment of exposed persons may become quite expensive, so that mass chemotherapy then becomes preferable to the selective treatment of individuals.

New schemes

Upgrading of existing schemes may be needed to improve productivity or to reduce health risks and should generally take priority over developing new schemes. Attention should be paid not only to the technical improvements required but also to the need for better management of schemes and to their improved operation and maintenance.

A pilot project is particularly necessary in countries with little or no experience of the planned use of excreta or wastewater. The problem of health protection is only one of a number of interconnected questions that are difficult to answer without local experience of the kind a pilot project can give. A pilot project should

- Wastes quality. It may be more fruitful to monitor the functioning of the treatment system than to take frequent samples for analysis. The Engelberg guideline values are intended not as standards for quality surveillance but as design goals for use in planning a treatment system. The lack of laboratory capacity for monitoring quality is not an adequate reason for not using wastes.

- Crop quality. Microbiological monitoring of crops is the task of the Ministry of Health as enforcer of public health regulations.

- Disease surveillance. This should focus upon farm workers. The minimum for any scheme is regular stool survey of a sample of workers for intestinal parasites. Where typhoid is endemic, a serological survey can be carried out at the same time.