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 reliably produced by treatment in a well designed series of waste stabilization ponds.

Guidelines for the microbiological quality of treated excreta and wastewater for aquacultural use were developed at the Second Project Meeting held in Adelboden, Switzerland, in June 1987. These recommend zero viable trematode eggs per litre or per kilogram (on an arithmetic mean basis), and less than 10000 faecal coliform bacteria per 100 millilitres or 100 grams (on a geometric mean basis). Such a stringent trematode guideline is necessary as these pathogens multiply very greatly in their first intermediate aquatic host. The value for faecal coliforms assumes a 90% reduction of these bacteria in the pond, so that fish and aquatic vegetables are not exposed to more than 1000 faecal coliforms per 100 millilitres.

Sociocultural aspects

Human behavioural patterns are a key determinant in the transmission of excreta-related diseases. The social feasibility of changing certain behavioural patterns in order to introduce excreta or wastewater use schemes, or to reduce disease transmission in existing schemes, can be assessed only with a prior understanding of the cultural significance of practices that appear to be social preferences yet which facilitate disease transmission. Cultural beliefs vary so widely in different parts of the world that it is not possible to assume that excreta or wastewater use practices that have evolved in one area can readily be transferred to another. A thorough assessment of the local sociocultural context is always necessary during the project planning stage, otherwise the project may be confidently expected to fail.

Environmental aspects

Properly planned and managed excreta and wastewater use schemes can have a positive environmental impact, as well as increasing agricultural and aquacultural yields. Environmental improvement results from several factors, including:

- Avoidance of surface water pollution, which occurs if unused wastewaters are discharged into rivers or lakes. Major pollution problems such as dissolved oxygen depletion, eutrophication, foaming and fish kills can be avoided.

- Conservation or more rational usage of freshwater resources, especially in arid and semi-arid areas: fresh water for urban demand, wastewater for agriculture.

- Reduced requirements for artificial fertilizers, with a concomitant reduction in energy expenditure and industrial pollution elsewhere.

- Soil conservation through humus build-up and prevention of land erosion.

- Desertification control and desert reclamation through irrigation and fertilization of tree belts.

- Improved urban amenity through irrigation and fertilization of green spaces for recreation and visual appeal.

Soil and groundwater pollution are potential disadvantages of the agricultural use of excreta and wastewater which can be minimized by scientifically sound planning and effective management of irrigation and fertilization regimes.

Technical options for health protection

Available measures for health protection can be grouped under four main headings:

- treatment of waste;

- crop restriction;

- waste application methods;

- control of human exposure.

It will often be desirable to apply a combination of several methods. The technical factors affecting each option are considered.

Waste treatment

The degree of pathogen removal by a waste treatment process is best expressed in terms of log,, units. The Engelberg quality guideline for unrestricted irrigation requires a bacterial reduction of at least

4 log units and a helminth egg removal of 3 log units. Helminth removal alone is sufficient to protect field workers. A lesser degree of removal can be considered if other health protection measures are envisaged or if the quality will be further improved after treatment. This can occur by dilution in naturally occurring water, by prolonged storage or by transport over long distances in a river or canal.

Without supplementary disinfection, conventional processes (plain sedimentation, activated sludge, biofiltration, aerated lagoons and oxidation ditches) cannot produce an effluent that complies with the Engelberg guideline for unrestricted irrigation. Moreover, conventional wastewater treatment systems are not generally effective for helminth egg removal.

Waste stabilization ponds are usually the wastewater treatment method of choice in warm climates. A series of ponds with a total retention time of about 11 days can be designed to achieve adequate helminth removal; depending on temperature, about twice that time is usually required to reach the bacterial guideline. The high degree of confidence with which pond series can meet the Engelberg guidelines is only one of their many advantages: others are low cost and simple operation. The only disadvantage of pond systems is the relatively large area of land required.

Disinfection-usually chlorination-of raw sewage has never been fully achieved in practice, but it will reduce the numbers of excreted bacteria in the effluent from a conventional treatment plant. However, a high, uniform and predictable level of disinfection efficiency is extremely difficult to maintain, and chlorination also leaves most helminth eggs unharmed.

Another problem is the cost of chlorine. A more appropriate treatment option is to add one or more ponds in series to a conventional treatment plant. The addition of polishing ponds is a suitable measure to upgrade an existing wastewater treatment plant.

Excreta treatment is not required for excreta applied to the land by sub-surface injection or placed in trenches before the start of the growing season. To achieve the guideline for helminthic quality, excreta must be stored for at least a year at ambient temperatures; alternatively, nightsoil and septage can be directly treated in waste stabilization ponds,

Heat treatment of excreta. Two methods of treating excreta at high temperatures may be used to reduce the minimum 12-month storage period needed to reach the Engelberg standard:

- batch thermophilic digestion at 50 °C for 13 days;
- forced aeration cornposting.

From the agricultural viewpoint cornposting has several advantages.

Crop restriction

Agriculture. If the Engelberg standard is not fully met, it may still be possible to grow selected crops without risk to the consumer. Crops can be broadly categorized according to the required extent of health protection measures:

Category A-Protection needed only for field workers. Includes industrial crops such as cotton, sisal, grains and forestry, as well as food crops for canning.

Category B-Further measures may be needed. Applies to pasture, green fodder and tree crops and to fruit and vegetables that are peeled or cooked before eating.

Category C-Treatment to Engelberg "unrestricted" guidelines essential. Covers fresh vegetables, spray-irrigated fruit, and parks, lawns and golf courses.

Irrigation limited to certain crops and conditions, such as Category A, is commonly referred to as restricted irrigation.

Crop restriction provides protection to consumers but not to farm workers and their families. It should be complemented by other measures, such as partial waste treatment, controlled waste application or human exposure control. Partial treatment to the helminthic part of the Engelberg quality guideline would protect the health of field workers in most settings and is cheaper than full treatment.

Crop restriction is feasible and is facilitated in several circumstances, including the following:

- where a law-abiding society or strong law enforcement exists;
- where a public body controls allocation of the wastes;
- where an irrigation project has strong central management;

- where there is adequate demand for the crops allowed under crop restriction and where they fetch a reasonable price;
- where there is little market pressure in favour of excluded crops (such as those in Category C).

Application of wastewater and excreta

Wastewater in agriculture. Irrigation water, including treated wastewater, can be applied to the land in the following five ways:

- by flooding (border irrigation), wetting almost all the land surface;
- by furrows, wetting only part of the ground surface;
- by sprinklers, in which the soil is wetted in much the same way as by rain;
- by subsurface irrigation, in which the surface is wetted little but the subsoil is saturated;
- by localized (trickle, drip or bubbler) irrigation, in which water is applied at each individual plant at an adjustable rate.

Flooding involves the least investment but probably the greatest risk to field workers.

If the water is not of Engelberg bacterial quality but is required for use on Category B crops, sprinkler irrigation should not be used except for pasture or fodder crops, and border irrigation should not be used for vegetables.

Subsurface irrigation can give the greatest degree of health protection as well as using water more efficiently and often producing higher yields. However, it is expensive and a high degree of reliable treatment is needed to prevent clogging of the small holes (emitters) through which water is slowly released into the soil. Bubbler irrigation, developed for localized irrigation of trees, avoids the need for emitters to regulate the flow to each tree.

Excreta in agriculture. Untreated or insufficiently treated excreta should be applied to land only by placing it in covered trenches before the start of the growing season, or by subsurface injection using specialized equipment. Nightsoil treated only to the helminthic quality guideline may pose a greater risk to field workers than restricted irrigation with wastewater; the risk can be minimized only by exposure control measures.

Aquaculture. Keeping fish in clean water for at least 2 to 3 weeks before harvest will remove any residual objectionable odours and reduce contamination with faecal microorganisms. However, such depuration does not guarantee complete removal of pathogens from fish tissues and digestive tracts unless the contamination is very slight.

Human exposure control

Agriculture. Four groups of people can be identified as being at potential risk from the agricultural use of wastewater and excreta:

- agricultural field workers and their families;
- crop handlers;
- consumers (of crops, meat and milk);
- those living near the affected fields.

Exposure of field workers to hookworm infection can be reduced by continuous in-field use of appropriate footwear, but this may be quite difficult to achieve.

Immunization against helminthic infections and most diarrhoeal diseases is not feasible, but it may be worth immunizing highly exposed groups against typhoid and hepatitis A. Additional protection may be afforded by adequate medical facilities, by regular chemotherapeutic control of intense nematode infections in children, and by control of anaemia. Chemotherapy and immunization cannot be considered an adequate strategy but could be beneficial as temporary palliative measures.

Risks to consumers can be reduced by thorough cooking and by high standards of hygiene. Tapeworm transmission can be controlled by meat inspection.

Local residents should be fully informed of the location of all fields where human wastes are used so that they and their children may avoid them. There is no evidence that those living near wastewater-irrigated fields are at significant risk from sprinkler irrigation schemes, but sprinklers should not be used within 50-100 m of houses or roads.

Aquaculture. Schistosomiasis is best controlled by treatment and snail control. Regular chemotherapy would be beneficial in endemic areas. Local residents should be informed which ponds are fertilized with wastes. Provision of adequate sanitation and clean water supplies is also an important factor in limiting human exposure.

Planning and implementation

Resources planning

The use of wastewater and excreta touches the responsibilities of several ministries or agencies. The active participation of the Health and Agriculture Ministries is especially necessary. It is usually advantageous to establish an interagency committee or possibly a separate parastatal organization to be responsible for the sector, whose first task, as an integral part of water resources planning, is to establish a national plan for wastes reuse. This will normally include plans to improve existing reuse practices as well as to implement new reuse projects.

Improvement of existing practices

The use of human wastes for crop and fish production often takes place illegally and without official recognition by the health authorities. Banning the practice is unlikely to reduce either its prevalence or the public health risk involved, and may make it more difficult than ever to supervise and control. A more promising approach is to provide support to improve existing use practices, not only to minimize health risks but also to increase productivity.

Some legal control will usually be required, although it is easier to make regulations than to enforce them. Measures to protect public health are particularly difficult to implement when there are many individual sources or owners of the waste. The measures required to bring the waste under unified control will often entail setting up new schemes.

The first stage in any attempt to improve existing practices must be a diligent effort to identify them, combined with tactful and informal conversations with farmers, local officials and interested local bodies. Where an existing practice contravenes regulations, it is important to investigate why those regulations are not being enforced: possible reasons range from inappropriate standards to lack of resources for enforcement.

Policy options

The following sections consider the feasibility, planning and implementation of the available options.

(a) Treatment

Wastewater. Treatment is difficult to implement when wastewater comes from a variety of sources, such as overflowing septic tanks. One approach may be to take action against those who produce the wastewater, to prevent the environmental pollution it causes. In other cases, the only solution may be to build a sewer system and sewage treatment works.

Excreta. Treatment is much more readily implemented where a single body such as a municipality collects or at least treats the excreta. Local demonstration plots may persuade individual farmers to treat excreta, by showing that crop yields are increased. This is a job for the agricultural extension service.

Aquaculture. One treatment option for aquaculture is to connect ponds in series (or to divide one pond into compartments connected in series), and avoid harvesting from the first pond. It may be necessary to establish cooperative arrangements between the owners of the different ponds.

(b) Crop restriction

The enforcement of crop restrictions on a large number of small farmers can be difficult but not impossible. In some countries, the existing agricultural planning machinery allows firm control of all crops grown. However, where there is no local experience, the feasibility of crop restrictions should first be tested in a trial area. Arrangements are needed for marketing permitted crops, as well as for assisted access to agricultural credit.

(c) Application

A change in irrigation method to reduce health risks is most needed when the current practice is flooding. Farmers may need help with preparing the land to make other methods possible. Arguments that 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 operate for at least one growing season and may then be translated into a demonstration project with training facilities for local operators and farmers.

Project planning

In many respects, planning requirements for excreta and wastewater use are similar to those for any other irrigation and fertilization schemes. For each scheme, the planner should seek to maximize benefits in a manner consistent with the need to protect health and minimize costs. Assessing the benefits requires a forecast not only of crop yields but also of prices. This in turn demands a survey to establish that an adequate market exists for the crops.

For the plan to be useful it must take account of the time-scale. A 20-year planning horizon is often considered for irrigation projects, with a modest beginning followed by phased expansion. Wastewater projects will be affected by progressive change in the quantity and quality of wastewater available.

The organizational pattern of a wastes reuse scheme will be determined largely by the existing land use patterns and institutions. Farmers need security of tenure of their land and of their right to the wastewater, especially if they are to make capital investments or change to new crops.

Large schemes need a full-time professional management staff, preferably under a single agency. Issuing and renewing permits for use of the resource can be made conditional on the observance of sanitary practices. It is common to deal with the farmers or pond owners through users' associations, giving them the task of enforcing the regulations that must be complied with for a permit to be renewed.

A joint committee or management board, which may include representatives of these associations, as well as of any particularly large users, of the authorities that collect and distribute the wastes and of the local health authorities, has proved its worth in many schemes.

Various support services to farmers are relevant to health protection and should be considered at the planning stage. They include the supply of farm machinery, agricultural credit, marketing services, primary health care and training. It is often necessary to begin training programmes before the start of the project. Similarly, the likely need for extension services must be estimated, and provision made for them to be available to farmers after implementation.

Legislation

The introduction or promotion of new projects for agricultural or aquacultural use of wastewater or excreta may require legislative action. Five areas deserve attention:

- creation of new institutions or allocation of new powers to existing bodies;
- roles of and relationships between national and local government in the sector;
- rights of access to and ownership of the wastes, including public regulation of their use;
- land tenure;
- public health and agricultural legislation: waste quality standards, crop restrictions, application methods, occupational health, food hygiene, etc.

Economic and financial considerations

Economic appraisal considers whether a project is worthwhile; financial planning looks at how projects are to be paid for. Improvements to existing practices also require some financial planning.

Economic appraisal. The economic appraisal of wastewater irrigation schemes must compare them with the alternative-what would be done in the absence of the scheme. The cost of the wastewater includes the cost of any additional treatment required, of conveying it to the field and of applying it to the crop. However, it is essential to subtract from this the cost of the alternative arrangements for wastewater disposal if the project were not implemented.

The economic appraisal of excreta use and aquacultural schemes is less sophisticated, as some of the benefits are more difficult to quantify.

Financial planning. A charge is normally levied for distributing the waste to farmers, the level of which must be decided at the planning stage. A farmer will pay for wastewater for irrigation only if its cost is less than that of the cheapest alternative water and the value of the nutrients it contains. In the case of aquaculture and the use of

- 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.