8
Planning and implementation

8.1 Resources planning

8.1.1 Wastes reuse and national development

The scarcity of surface and ground water in many countries has led, or is leading, to the development of national plans for the rational allocation, utilization and protection of all available water resources. The objective of such plans is to ensure, as far as is practically possible, the maximum economic yield from the use of a scarce resource. Human wastes are relevant to these national water plans as they can alter the physicochemical and microbiological quality of water and thus place restrictions on its use. The incorporation of wastes reuse planning protocols into national water plans is important, especially under conditions of water scarcity, not only to protect water quality but also to minimize treatment costs, to safeguard public health and to obtain the maximum possible agricultural and aquacultural benefit from the nutrients and organic matter contained in the wastes.

Once it is recognized that human wastes reuse is an integral part of national water resources development planning, it is possible to establish a national plan for wastes reuse. This will normally include plans to improve existing reuse practices as well as for new reuse programmes and projects. This section provides guidance on how such a plan may be established.

8.1.2 Institutional framework

At national level the use of wastewater and excreta is an activity that touches the responsibilities of several ministries or agencies. The principal ministerial responsibilities are usually more or less as follows, although some countries have different arrangements:

- **Ministry of Agriculture and Fisheries**: overall project planning; management of state-owned land; installation and operation of irrigation infrastructure; agricultural and aquacultural extension, including training; control of marketing.

- **Ministry of Health**: health protection, particularly establishment of quality standards, monitoring methods and schedules for treated excreta and wastewater; health education; disease surveillance and treatment.

- **Ministry of Water Resources**: integration of wastewater use into water resources planning and management.

- **Ministry of Public Works/Local Government**: excreta and wastewater collection and treatment.

- **Ministry of Finance and Economic Planning**: economic and financial appraisal of projects; import control (equipment, fertilizers).

Other ministries and government agencies, for example those concerned with environmental protection, land tenure, rural development, cooperatives and women's affairs, may also be involved. Unfortunately, the Ministry of Health is often only marginally involved in the sector, if at all, even where human wastes are used on a wide scale. Any effort to control the health risks from the practice will be greatly strengthened by the active participation of the Health Ministry. When implementing any new project or health protection measure that involves a change in farming practice, the Ministry of Agriculture will have a fundamental role to play.

Smooth cooperation between the relevant agencies is required, particularly between the technical staff involved. Some countries, especially those in which there are few natural water resources, may find it advantageous to establish an executive body, such as an interagency technical standing committee, under the aegis of a leading ministry (Agriculture or Water Resources), or possibly a separate parastatal organization (with both government and private capital) such as an Office for Wastewater Recycling (as in California, see Box 8.1), to be responsible for sector development, planning and management. Another approach (followed in Tunisia, see Box 8.2) is to include the promotion of waste recycling as a goal of the International Drinking Water Supply and Sanitation Decade, under an interministerial National Decade Coordinating Committee. Legal powers will be needed for this purpose.

Most countries, however, will not feel the need for such a formal arrangement, and a simple *ad hoc* committee will often suffice. Alternatively, existing organizations may be given responsibility for the sector, or parts of it; for example, a National Irrigation Board

Box 8.1 Wastewater use management in the United States of America

In the United States no single federal agency controls wastewater use, but several agencies have relevant responsibilities. The federal government has mandatory requirements on quality of sewage discharge, as well as providing grant funding for wastewater use projects. In this respect, the Environmental Protection Agency has the greatest influence on wastewater reclamations as its primary function is to enforce the provisions of the Federal Water Pollution Control Acts and other related federal legislation. Other federal agencies, such as the Bureau of Reclamation, have become involved in wastewater reclamation as a means of supplementing existing water resources.

On a state basis, the policies and agencies are varied, primarily as a result of varying views on the value of wastewater use as part of the overall resource. Perhaps the best example of a comprehensive state programme is that developed by California, where wastewater use is an integral part of water resource planning. In 1977 the State Water Resources Control Board adopted the Policy and Action Plan for Water Reclamation in California, which includes funding for projects that make beneficial use of wastewaters. The plan also includes guidelines for project implementation. In addition the Governor created an Office of Water Recycling within the State Board to promote wastewater use within the state. The Office has two committees: one is for interagency coordination, and the second is an advisory committee composed of representatives of the water community together with technical specialists. The state's Regional Water Quality Boards are responsible for coordination at the local level, including the evaluation of applications for wastewater use permits and the enforcement of any restrictions on wastewater use.

Source: Fordham (1984).

might be made responsible for wastewater use in agriculture, and a National Fisheries Board for the aquacultural use of excreta and wastewater. Such an organization should then convene a committee of representatives from the different agencies having sectoral responsibilities.

Setting up an interagency or interministerial committee involves a compromise between representatives at too high a level, who are often too busy to meet, and those at too junior a level, who are unable to take decisions or to ensure they are implemented. The most likely problem in the long term is that the committee will fail to meet regularly. Its terms of reference should therefore lay down a mini-

Box 8.2 Management of wastewater use in Tunisia

The Water Law, enacted in 1975, stipulates that water resource planning must start from the principle of making the fullest possible use of every cubic metre of water. This includes the use of all treated wastewater, which has been set by the National Sanitation Commission as one of the objectives for the Water Supply and Sanitation Decade.

Initial studies are carried out by ONAS (*Office Nationale de l'Assainissement*), the national sanitation agency, which has recently examined plans for 20 new schemes. Many of the schemes are on state-owned land (*terres domaniales*) occupied by tenant farmers. The construction of works to transport and distribute the treated wastewater from the treatment plant to the irrigated area is carried out by the Directorate of Hydraulic Works in the Ministry of Agriculture.

The system is then operated by local Agricultural Development Authorities, also under the Ministry of Agriculture, which charge for the water and have powers to fine or disconnect supplies to farmers who disobey crop restriction regulations.

Elsewhere, the Ministry of Agriculture may authorize private companies to manage wastewater irrigation schemes, as in one case where the management of a hotel complex is authorized to irrigate with the treated wastewater from the hotel. The authorization documents include a restriction to lawns (including a golf course), ornamental plants and non-fruit trees, as well as a set of provisions (a *cahier des charges*) specifying the rights and duties of the hotel management, the Ministry of Agriculture, ONAS and the Ministry of Public Health.

The Ministry of Public Health is responsible for the hygienic quality of the wastewater used for irrigation and of the crops marketed. It is also responsible for monitoring of water pollution and enforcement of pollution control regulations, and plays an important role in formulating the regulations affecting the use of wastewater.

Source: Strauss (1986b).

mum frequency for meetings, and this is most likely to be sustained if a single interested person or department is responsible for calling regular meetings and following up decisions.

In countries with a regional or federal administration, such arrangements for interagency collaboration will be still more important at regional or state level. Whereas the general framework of wastes use policy and standards may be defined at national level, the regional body will have to interpret and add to these in the light of local conditions. An example of this is the relationship between federal and state bodies in the United States (see Box 8.1).

With regard to health protection measures, the interministerial body's main tasks would be:

- to develop a coherent national or regional policy and monitor its implementation;
- to define the division of responsibilities between the respective ministries and other bodies involved in the sector, and the form of liaison between them;
- to appraise major proposed new schemes from the point of view of public health and environmental protection;
- to oversee the promotion and enforcement of national legislation and codes of practice;
- to develop a coherent manpower development policy for the sector.

The institutional framework at the level of the individual project is discussed in Section 8.3.4.

8.2 Improvement of existing practices

Human wastes are already used for crop and fish production in many countries, often illegally and without official recognition by the health authorities. Where the practice is traditional or has arisen spontaneously, untreated or insufficiently treated wastes are commonly used. Experience in many countries has shown that simply to ban the practice is not likely to have very much effect on its prevalence or on the public health risk involved. On the contrary, banning the practice does not necessarily stop it, but may make it more difficult to supervise and control, and may also interfere with disease surveillance and health care among those most exposed to the risk of infection. A more promising approach is to provide support to improve existing use practices, not only to minimize the health risks but also to increase productivity.

Some legal controls will usually be required as well. However, it is easier to make regulations than to enforce them. In drafting new regulations (or in choosing which existing ones to enforce) it is important to plan for the institutions, staff and resources necessary to ensure they are followed. Perhaps even more important is to ensure that the regulations are realistic and achievable in the context in which they are to be applied. It will often be advantageous to adopt a gradual approach, or to test a new set of regulations by persuading a local administration to pass them as by-laws before they are extended to the rest of the country.

Measures to protect public health are particularly difficult to implement when there are many individual sources or owners of the waste, whether these are individual septic tank overflows, nightsoil collectors, or farmers with riparian rights to pump from a river so polluted as to contain only slightly diluted sewage. If the waste can be brought under unified control by installing a sewerage system, by establishing a central nightsoil treatment plant or by diverting the sewage from the river to a treatment works, this will give the controlling body much greater power to influence the ways in which the waste is subsequently used, and thus to minimize the risk to health. As can be seen from these examples, the measures required to obtain this control will often amount in practice to setting up a new scheme. This is discussed in Section 8.3.

8.2.1 Surveys

The first stage in any effort to improve existing practices must be to find out what those practices are and on what scale they are to be found. Such practices are often illegal, or believed to be so, and therefore are not likely to be mentioned in official documentation. Moreover, farmers may not be willing to let officials know that they use wastewater or excreta, for fear of being prosecuted or possibly obliged to pay for the wastes they use. There is therefore no substitute for a diligent search for the practice in the field, combined with tactful informal conversations with farmers and local officials. Interested local bodies, such as farmers' associations, marketing organizations and nongovernmental community organizations, may sometimes be better informed than government officials.

A visit to all wastewater outlets and a short walk downstream from each of them will often reveal surprises, as will an inspection of nightsoil disposal sites. The staff at such sites and at sewage treatment works will usually be well aware of any agricultural or aquacultural use of wastes in the area. So also will health inspectors, though they may need to be reassured that, if they are unable to enforce regulations, this is not necessarily a reflection upon their competence, diligence or integrity.

Wastewater is often used informally after it has been discharged and diluted in a natural watercourse. The associated health risk may be practically the same as if undiluted wastewater had been used, especially when the natural flow in the river or stream is little more than the flow of sewage in the dry season (when the water is most likely to be used). In some cases, on-site excreta disposal systems are also involved. Overflowing effluent from septic tanks may be used to irrigate gardens and vegetable patches in urban areas, and latrine pits may be emptied informally to fertilize nearby fields or fishponds.

At this stage, the survey should be kept as informal and open-ended as possible. Later, when the principal questions are clear and quantitative data are needed, a structured interview of farmers may be used (see Simpson-Hebert, 1983).

The results of the survey may be surprising and possibly shocking, and a tempting response may be to enforce blanket prohibitions, especially where such regulations already exist. However, such action is likely to be ineffective and even counterproductive, and is best avoided until the policy alternatives described below have been carefully considered. It is also advisable to assess the health risks of any waste recycling practices in the context of general patterns of hygiene and disease transmission in the area. For example, faecal coliforms or *Ascaris* eggs may be found on vegetables fertilized by wastewater, but such contamination should be compared with that found on the same products, grown by other methods, at local points of sale such as markets. An epidemiological survey among farm workers may also help to put health risks in perspective (see Box 8.3). If the farm workers eat some of their own produce then they (and their families) are the group most exposed to the risk of infection.

An informal survey of reuse practices should aim not only to find out where wastes are being used, but also to answer the following questions:

- How are the wastes collected, treated and stored?
- What quantities are used?
- What quantities are available?
- On which crops are they applied?
- What are the benefits of using them?
- How and when are they applied?

Box 8.3 Assessment of health risks by epidemiological surveys

An epidemiological survey among farm workers would aim to assess the amount of disease caused by the practice of using human wastes. This can be done by comparing the level of disease in the 'exposed' population (which uses wastes) with that in an 'unexposed' or control population (which does not). The difference in disease levels may then be attributed to the practice of using the wastes, provided that the two populations compared are similar in all other respects including socioeconomic status and ethnic group.

It is best to restrict the study to the excreta-related diseases of most importance in farm workers locally. These will usually include intestinal helminth infections and diarrhoeal disease and, in some areas, typhoid fever and hepatitis A infection. Where aquaculture is practised, particular helminthic infections may be important, e.g. clonorchiasis, schistosomiasis.

The choice of infections for study and the method of study should also be guided by practical considerations. In a one-off, cross-sectional survey, the size of the sample needed will depend on the prevalence of the infection and on the difference in prevalence between the two groups that the study aims to detect. In general, large sample sizes are needed when the prevalence of the infection is low. This means that a study of the prevalence of diarrhoeal disease in farm workers will normally need a larger sample size than a study of intestinal helminth infections (for example, *Ascaris, Trichuris* and hookworm). The following two examples give an idea of the sample sizes required to have a 90% chance of detecting a difference at the 5% level of statistical significance:

- A sample size of about 230 per group would be needed where the prevalence of *Ascaris* infection in the general (unexposed) population is 30% and has been raised to 45% in the exposed population.

- About 1720 people would be needed in each group where the prevalence of diarrhoeal disease in the general (unexposed) population is 5% and has been raised to 7.5% in the exposed population.

Diarrhoeal disease is common but has a low prevalence at any given moment because of the short duration of each episode. For this case, the necessary sample size could be reduced by using a prospective cohort study, which monitors the incidence of disease over a period of time. This is, however, much more difficult to organize.

Sample sizes should be calculated with reference to appropriate

(Box 8.3 continued)

statistical texts (for example: Fleiss, 1981; Lwanga & Lemeshow, 1989) and by consulting WHO guidelines (for example, World Health Organization, 1981b).

An epidemiological survey is a complex undertaking and should involve trained staff in the Ministry of Health. The study should be led by an epidemiologist, and a statistician should be involved at an early stage to help in survey design as well as analysis of the data. A study will normally go through four phases:

1. the preparatory work, including study design and identification of the sample population and questionnaire development;

2. the pilot study, to judge the feasibility and appropriateness of the study, train field workers and refine the questionnaire;

3. the field work proper;

4. analysis of the data.

Guidelines on the conduct and interpretation of studies in environmental epidemiology have been published by WHO (1983). Although these guidelines deal mainly with the effect of chemicals and with chronic disease, they are also very relevant to studies of the effect of wastes reuse on infectious diseases.

Source: U. Blumenthal, personal communication.

Answers to the last question may suggest possible interventions. Some aspects of the existing practice may already help to reduce the health risk — for instance when nightsoil is buried before planting — and these can provide a basis for further improvements.

It will also be helpful to examine the organizational setting. The farmers may own the land, or they may be employees, tenants, share-croppers or squatters. They may or may not be free in practice to choose their crop or their agricultural (or aquacultural) methods, because of their status or because of marketing constraints. If health risks are to be reduced, someone will have to be persuaded, induced or obliged to change the present practice, and this may not necessarily be the person working in the field.

8.2.2 Existing regulations

If it is considered that the use of human wastes in agriculture or aquaculture is posing a health risk, it will be useful to study the existing relevant legislation and regulations before considering the policy options to minimize that risk. These will include the Water Law, where it exists, as well as legislation on environmental pollution, water quality, food hygiene and occupational health.

In many cases it will be found that this legislation is regularly being flouted, especially where there are strong economic motives for doing so. This can happen, for example, near large cities in arid regions, where the city wastewater may be a priceless resource not so much because it contains wastes but rather because it is almost the only water available. Farmers in such areas have been known to break open sewers to divert raw wastewater on to their land. In areas of high population density the production of crops, and sometimes fish, is often so intense that every hectare must produce the maximum amount possible. Excreta then become very valuable because of their nutrient content. In parts of Asia, for example, it has been known for the contents of a latrine to be stolen at night for use in agriculture.

When human wastes become valuable, whether because of the water that carries them or for the nutrients they contain, farmers will wish to use such a precious resource on the most profitable crop. Where the farmers are poor or lack secure tenure of the land, an additional factor in their choice of crop may be their need for a quick return on the money they invest. A squatter, for example, cannot usually wait for fruit trees to mature, lest he be evicted and the site bulldozed for a new building. The crop will therefore often be a vegetable crop and it may sometimes be eaten raw.

Where current reuse practice contravenes existing regulations, it is important to investigate the reasons why these regulations are not being enforced. Unless the various reasons for non-enforcement, outlined below, can be eliminated, future legislation is likely to fare no better.

Inappropriate standards

Rightly or wrongly there may be a general consensus that there is no serious health risk or that to enforce the regulations will not significantly reduce it. Alternatively, there may be ignorance of measures to minimize the health risk other than those that would seriously prejudice the farmers' income. If there is in fact no health risk, there is no need for enforcement. If there is a risk, then motivation of enforcement staff by educating them about the existing health risk and training them in low-cost ways to minimize it should become a priority.

In many cases, regulations such as wastewater quality standards have been borrowed from other countries with no consideration of their suitability for local conditions. Others have been adopted for reasons quite unconnected with epidemiological evidence of whether or not they are necessary. For example the only state in the USA that has adopted a virological standard of wastewater quality for reuse happens to have a university that has developed techniques for the virological examination of wastewater.

The thoughtless borrowing or introduction of over-stringent regulations can have one of two outcomes. Either the regulations will be flouted, creating the same health risks as if they did not exist; or they will cause an unnecessary fear of prosecution or disease and thus squander resources by discouraging all use of human wastes. A more realistic set of standards, which are totally adequate to safeguard public health, would be based on the Engelberg guideline values (see Tables 1.4 and 1.6).

Ignorance of the relevant legislation

This is best dealt with by education and training of the enforcement staff.

Lack of resources

It is usually a job for health inspectors to ensure that, where it is permitted, the use of wastes to produce crops or fish is carried out in a hygienic manner as prescribed by law. In some cases, the Ministry of Agriculture or the authority that manages a wastewater irrigation system may be responsible for applying crop restrictions or for otherwise regulating agricultural practices. Whichever arrangement has been adopted, the relevant body must rely on its field staff to police the regulations that it administers. Field staff, however, are likely to have so many other pressing tasks that this one is neglected, or they may lack the means of transport required to make regular visits to the area.

It is arguably a good idea for the role of enforcement officer to be combined with that of extension agent or irrigation system manager. This will ensure that staff are in the area regularly, and also help the farmers to see them as colleagues rather than as opponents. However, more staff may be needed if health risks are to be controlled.

Lack of definition of responsibilities

Often, however, the problem is not so much a shortage of field staff as a lack of definition of who is to enforce the rules, of the degree of priority this task should have in job descriptions, and of how staff are to be supervised and called to account in the performance of this duty.

External pressure

A common problem is the tendency of prominent local citizens, who may own large areas of land or fish ponds, to try to use their influence to avoid the sanctions of the law. After a few such cases, enforcement officers such as health inspectors may give up trying, because it may be risky for them to prosecute such people. The problem is most likely to occur where the cost of compliance with the regulations is relatively high. The rate of compliance may be increased by relaxing the regulations, or by actively enforcing only those regulations that can be met relatively easily. An alternative approach, where the rules cannot be relaxed without an unacceptable health risk, is to bring the enforcement officers under close supervision from a higher level. A senior official from a national body is less likely to be suborned or intimidated than a health assistant employed by a local municipality.

8.2.3 Policy options

The available technical measures that can be taken to avoid the health risks of using wastes have been outlined in Section 7. In practice, in a context where excreta or wastewater is already being used, not all of these measures will be feasible or appropriate, and the choice of the most appropriate combination will depend on local circumstances.

It is advisable to start by choosing a few practical and possibly quite modest steps, which can be taken with the available resources, to give a progressive improvement in the situation. They could be implemented one by one, or tried in one area before being extended progressively until overall coverage is achieved. Whatever the coverage or time-scale involved, their implementation should be monitored to ensure that they are achievable and to rectify any mistakes.

The following sections consider the managerial factors relevant to the feasibility, planning and implementation of the available options. For each type of use, these are discussed under the headings used in Section 7, that is: treatment, crop restriction, application, and human exposure control.

Treatment

Wastewater. Treatment is an option that involves few technical problems when the wastewater collected by a sewerage system is to be used for irrigation. Its drawback is that it usually requires a substantial capital investment, although upgrading or improving the operation of existing wastewater treatment plants can sometimes be cheap and effective (see Section 7.2.5).

The building of a wastewater treatment plant on the most suitable available land will often alter the place where the wastewater is discharged. This will benefit the owners or occupiers of land near the new discharge site, while others may lose. It will be necessary to make some concessions to the latter if their cooperation is required; aggrieved farmers have been known to break open the sewers upstream of a new treatment plant so as not to lose their access to the raw sewage.

The land where untreated wastewater is used for agriculture will often be the most suitable land for the treatment plant, but its location on the outskirts of a city also makes it very desirable for building as the city expands. Indeed, it may already have been bought by speculators. If it is still in the hands of those who farm it, a strong inducement for them to sell at a reasonable price may be an offer of downstream land and water rights to allow them to continue using the treated effluent from the new plant.

Much uncontrolled use of wastewater is by abstraction from rivers that are so heavily polluted as to consist of only slightly diluted raw sewage. Sometimes it may be more feasible to cover the river as a sewer and treat the full flow, rather than to collect or treat the many small discharges into it. If it is decided to introduce or improve the treatment of wastewater discharged into such a river, consideration should be given to setting up a formal irrigation scheme to use the wastewater. This gives control of the wastewater and its use to a single authority, which greatly simplifies the implementation of other measures for health protection, as will be seen in the following paragraphs. The planning and implementation of such a scheme are further discussed in Section 8.3.

Treatment is a much harder option to implement when the wastewater in use comes from a variety of sources, such as over-flowing septic tanks. One approach may be to take action against those who produce the wastewater, to prevent the environmental pollution it causes. The owners of septic tanks, for example, could be obliged to build adequate soakaways and desludge the tanks to prevent blockage of those soakaways that still function. Even then, the safe use of the wastewater is not necessarily ruled out. The subsoil irrigation provided by soakaways may sustain hygienic and profitable small-scale urban agriculture in the gardens where they are located.

In other cases, the only solution may be to build major sanitation works. When large numbers of septic tanks overflow, for example, it may indicate that there is not enough room, in the circumstances, to build adequate soakaways: a small-bore sewerage network (Otis & Mara, 1985) is needed to collect the effluent. The effluent can then be treated in a single treatment works, thus greatly simplifying the technical and organizational aspects of treatment and subsequent reuse.

Excreta. In the same way, treatment of excreta is much more readily implemented where a single body such as a municipality collects the excreta and can also manage the treatment process. Careful supervision may be needed so that treatment — often a prolonged process — is carried out for the full period required. Otherwise, at times of great demand, it can be tempting to take short-cuts and allow the use of partially treated excreta.

When excreta from many small sources is used, it is rather harder to institute treatment separately at all of these sources. In some large Asian cities, where nightsoil is collected by many small entrepreneurs for sale to farmers on the outskirts, it might be possible for a municipal body to purchase the raw nightsoil from them and sell the treated product back to them. Since composted nightsoil is a more effective fertilizer, it may be possible to sell it for a slightly higher price, the difference going towards the cost of composting.

In rural areas, however, farmers who have used raw excreta for years will not be easily persuaded to treat it. They may find it hard to believe that such a long-established practice is harmful to their health. A more persuasive approach may be to show them, by the use of local demonstration plots, that higher crop yields are obtained with treated excreta. This is a job for the agricultural extension service.

Of course, for the agricultural extension officers to have a chance of success, the treated excreta must in fact be more effective and not too unattractive to use. Farmers may be discouraged from using excreta composted with solid waste if it contains large undigested items of debris from the solid waste. It may therefore be necessary to remove such debris from the compost to make it saleable.

Aquaculture. In traditional aquaculture using wastewater or excreta, treatment is probably the option most likely to succeed. One treatment option for aquaculture is to connect ponds in series (or to divide a pond into compartments connected in series) and avoid harvesting from the first pond. Existing ponds connected in series may have different owners, so that to promote this option it may be necessary to establish cooperative arrangements between them. Another approach may be to establish an uncontaminated depuration pond in which the fish are kept for several weeks before harvesting. This can be done by building a new pond, or by separating off part of an existing one.

Whatever method is used for health protection when using excreta in aquaculture, its implementation is likely to demand a change in behaviour, and probably the expenditure of money, by a large number of individual users, and again an additional motive is probably required. One such motivating factor might be the greater convenience and privacy of an inhouse toilet, the waste from which can be treated, compared with an overhung latrine over a fish pond.

Crop restriction

Crop restriction is relatively simple to implement where the wastes are used by a small number of large bodies, whether they are private firms, cooperatives, state farms, or the municipal authority itself. However, the enforcement of crop restrictions on a large number of small farmers is much more difficult. The edible crops most likely to be excluded, such as salad vegetables, are among those with the highest cash yields. There may be a good market for them in the nearby urban community producing the wastewater, and moreover their short growing season gives a relatively quick return on the cash invested by comparison with, say, fruit trees.

Crop restrictions are not impossible in such circumstances; they are most likely to succeed where local dietary habits limit the demand for uncooked vegetables, and where there are profitable alternative crops such as cereals, for which a market exists (see Box 8.4). Industrial crops, such as cotton, or grapes for wine production, can be particularly suitable for cultivation under crop restrictions (see Box 8.5).

In some countries, the existing agricultural planning machinery allows a firm control of all crops grown, with regular inspection of every farmer's fields and sanctions against those who depart from the plan. These arrangements can be used at little extra cost to ensure that crop restrictions are followed.

If there is no local experience of the application of crop restrictions, their feasibility should be tested in a trial area before they are

Box 8.4 Crop restriction in Irrigation District 03, Mexico

Where irrigation water contains untreated sewage, as occurs in District 03, national regulations restrict the crops grown to those that are eaten cooked, those eaten uncooked but which do not come into contact with the soil, and fodder crops. In each irrigation district, a local committee consisting of representatives of the Department of Agriculture and Water Resources (SARH) and of local groups makes agreements on water distribution, crop restrictions and cropping patterns. In District 03, the committee includes representatives from the local agriculture secretariat, local banks, agricultural industries, marketing groups, farm owners and cooperative farm workers, as well as members from SARH.

Prohibited crops include lettuce, cabbage, carrots, radishes, beet, coriander, spinach and parsley. The main crops grown are shown in the table below.

Crop	**Area cultivated (ha)**	**Percentage of total**	**Water requirement (cm)**	**Net profit per hectare (× 1000 pesos)**
Maize	19668	41.0	100	41.4
Alfalfa	17972	37.5	158	22.4
Barley	1852	3.9	72	15.8
Oats	1706	3.6	72	4.0
Wheat	458	1.0	113	11.6
Chillies	999	2.1	108	154.9
Green tomatoes	587	1.2	141	192.5
Haricot beans	865	1.8	31	20.1
Broad beans	301	0.6	88	18.3
Others	3574	7.3	97	58.6

The first five crops in the table are cereals and fodder crops, and account for 87% of the total area under cultivation. Compliance with the crop restrictions is enforced by SARH personnel in charge of each section of the District. However, because of the great demand for maize (the staple food) and fodder crops in Mexico, and since raw vegetables do not form a major part of the diet of most people, non-compliance with the restrictions is not a serious problem. Farmers are allowed to grow chillies and green tomatoes, which although they are eaten raw grow well above the ground and are therefore not usually contaminated by sewage used in surface irrigation. There is a strong demand by the farmers to grow these crops, because of their importance in the Mexican diet and their high economic return.

Source: U. Blumenthal, personal communication.

Box 8.5 Crop restriction in Ica, Peru

The town of Ica lies on the coast of Peru about 300 km south of Lima, and is surrounded by desert. It was traditionally a wine-producing area, but cotton began to compete with grapes in the early 1900s. Irrigation water was initially obtained from rivers and wells, but now wastewater is also used.

The majority of the sewage from Ica is treated in four waste stabilization ponds at Cachiche. However, the ponds are unfortunately connected in parallel and therefore produce a relatively poor quality effluent, with a faecal coliform concentration of about 10^5/100 ml. This effluent is used to irrigate about 400 hectares of land; because of the poor quality of the effluent, the cultivation of tubers and other vegetables that grow close to the ground, or that are consumed raw, is not permitted. The major crops grown are cotton, maize, and grapes. In addition, the sewage from Tinguina, a suburb of Ica, is treated in a single waste stabilization pond. The effluent is used to irrigate a further 130 hectares, where mainly cotton and fruit trees are grown. Near to these areas, ground water is used to irrigate vegetables and other crops that cannot be grown using the wastewater.

The successful operation of the ponds, use of the effluent and enforcement of crop restrictions can be explained by several factors: the history of cultivation of non-vegetable crops in the area, the availability of ground water to enable some farmers in the area to grow vegetables, and cooperation between the Water and Sewerage Service, which operates the sewage treatment ponds, and the Health Inspectorate, which enforces the regulations.

Source: U. Blumenthal, personal communication.

implemented on a wide scale. The trial will also give an initial estimate of the resources required for enforcement, as well as clarifying the most suitable institutional arrangements for implementation of restrictions. These should include arrangements for marketing those crops that are permitted, at a high enough price to interest the farmers. Where greater cash inputs or a longer growing season are involved, assisted access to agricultural credit may also be necessary.

Enforcement at the field may not always be as easy as might at first appear. Though a crop may take months to grow and can be inspected throughout this time, the wastewater may need to be applied for only a few days each month, and this can be concealed even from vigilant inspectors. Some of the lessons learned from the successful crop restriction system in Mexico are summarized in Box 8.6.

Another approach might be to monitor the microbiological quality of food sold at the market, although this has never been used in practice to enforce crop restrictions and would face several difficulties. First, a considerable amount of experimentation would be required to define achievable standards of quality. An *a priori* standard may not be met even by produce grown without the use of wastes, and any attempt to enforce it would be self-defeating. Second, it is not always easy to trace the origins of a consignment of agricultural produce sampled on a market stall, and less so when the results of microbiological examination are known, a day or two after sampling. Third, regular sampling from the many places where foodstuffs are sold would require laboratories with the capacity to analyse a formidable number of samples. On the other hand the collection of a few samples from market stalls for examination, with a possible threat of action against those producing or selling heavily contaminated foodstuffs, could have a salutary effect on food hygiene generally, including crops grown using wastes in areas unknown to the health authorities.

Box 8.6 Enforcement of crop restrictions

Crop restrictions have been enforced over many decades in the areas irrigated with wastewater from Mexico City. This experience has shown the need for a comprehensive programme to ensure compliance with the regulations, which should include the following principal components.

(a) A small but flexible and efficient inspection and regulatory service with well trained personnel able to identify the banned crops and the location of risk areas in terms of wastewater quality. Staff of this regulatory service must be instructed to perform their duties with dignity and honesty, trying to be advisors and educators rather than policemen. The use of an inspection operating manual and standardized forms is desirable. Under normal conditions, the immediate responsibility for successful implementation of crop regulations rests upon those in charge of irrigation permits and also upon the extension agents.

(b) The issue of permits based on a complete inventory of land and farms using wastewater. The permit form should include such data as name, land location, surface to be irrigated, water re-

(Box 8.6 continued)

quired and manner of application, crops and marketing arrangements. Permits should be renewable after each crop cycle.

(c) A well organized training programme with provisions for selecting manpower. Emphasis must be placed on the employment of professional personnel including sanitary engineers.

(d) Information on the crop regulations must be effectively disseminated. Wide publicity is required to alert enforcement staff, farmers and the public in general of the health risk involved in raw wastewater, the reasons why crops have to be controlled, and the need for their participation. The general public must be educated to recognize the need for these public health regulations, with greater public concern for improved public health and safer food production.

(e) The integration of activities necessitates cooperation and coordination among government agencies such as public health, agriculture, livestock and water authorities, at national, state and local levels. Trade and transportation authorities must be informed of the crop regulations related to places of crop production from sewage farms and the prohibited categories.

(f) To be effective, the regulatory agency and its activities must be established by law and firmly supported by law enforcement organizations. A legal advisory service is needed.

(g) Provision must be made for detecting and monitoring the microbiological and chemical quality of water, soil and crops. This requires adequate laboratory facilities for analytical work.

(h) The irrigation district should maintain up-to-date farm control records with periodic evaluation of data on excreta-related diseases.

(i) The entire crop control system requires careful technical and administrative supervision to ensure, for instance, that no inspectors succumb to corruption, as this would render it useless.

(j) Office support facilities and transportation are indispensable for the implementation of the programme.

Source: Romero (1987).

Application

Wastewater. Irrigation by sprinkler demands careful measures for the protection of the workforce and nearby residents from exposure to infection. However, sprinkler irrigation is unlikely to be practised except in large, centralized schemes run by a single body which is in a relatively good position to ensure that these other measures are implemented.

A change in an existing wastewater irrigation method to reduce health risks is most likely to be needed when the current practice is flooding. Farmers may not be very enthusiastic about the alternative (for instance furrow irrigation), as it is likely to involve them in additional work and expense. They may need help with levelling of the land and possibly with contour ploughing to create the furrows. The change will also help to reduce mosquito breeding and other forms of exposure to disease occasioned by wading in areas flooded with wastewater. In addition to the diminished risk to farmers' health, arguments that may persuade them to change might include the greater efficiency of other irrigation methods when limited quantities of water are available, and the reduced mosquito nuisance. The Agricultural Extension Service is best placed to encourage farmers to change their irrigation methods. Its task will be easier if a high enough charge is levied for the wastewater to encourage its efficient use.

Subsurface or localized (drip, trickle or bubbler) irrigation can give a still greater degree of protection from contamination as well as using water more efficiently and often producing higher yields. It is expensive, however, and has not yet been used on a wide scale for irrigation with wastewater. A high degree of reliable treatment is required, to prevent clogging of the small holes (emitters) through which water is slowly released into the soil, although this is not a problem with bubbler irrigation.

Excreta. As is the case for wastewater, the Agricultural Extension Service may be in the best position to promote hygienic practices relating to the application of excreta. Where a municipal body controls the source of nightsoil, it may be able to encourage application before the start of the growing season by making the nightsoil available only at certain times of the year. Alternatively, the agency controlling distribution of the nightsoil may itself apply it to the farmers' fields and charge them for this service. The workers handling the excreta will then be the employees of a single body, which will facilitate exposure control measures among them.

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. They include health education, particularly regarding domestic hygiene and breast-feeding, and the promotion of oral rehydration solutions prepared from sachets or from ingredients available in the home.

An obvious measure is to provide an adequate water supply and sanitation. Controlling the exposure of agricultural workers to faecal contamination in the fields may have little effect if they continue to be exposed to infection from their drinking-water and in their home environment through lack of these basic facilities. Particular care is required to ensure that the use of human wastes does not cause contamination of nearby wells or other sources of drinking-water

Where salaried agricultural workers are involved, their employers have a responsibility to protect them from exposure to diseases, which in many countries is set down in existing legislation on occupational health. This may need to be brought to the employers' attention, together with guidance on the measures they should take such as the issuing of protective clothing, particularly footwear. Employers often despair of issuing footwear, claiming that their workers do not use it, or that they sell it or save it to wear on special occasions. Any effort to promote the issuing of protective clothing by employers must be accompanied by still greater efforts to convince their employees that they must wear it.

Measures to control the exposure of those who handle the crops can be implemented in much the same way as for farm-workers. When they all work for a small number of employers, exposure control fits into a general programme of occupational health. On the other hand, when a large number of petty traders are involved, selling or making products from the crops, it will be difficult to implement exposure control measures unless they are all gathered together in a market. Most markets are in any case subject to public health inspection, and basic exposure control measures may be a good thing whether or not crops produced using wastes are being handled. As well as protecting crop-handlers from contamination, they may also help to protect other crops from contamination by the handlers.

Markets may also be the best places to advise consumers about the hygienic precautions they should take with the produce they purchase. It is certainly good for consumers to be told of anything they can do to protect themselves from exposure to infection. However, they cannot be relied upon to do it, especially where it would mean a change from long-standing habits.

Residents who are not involved in the use of wastewater or excreta are best placed to ensure that their health is not put at risk by those who are, once it has been explained to them what precautions are required and what risks they and their families may run if the precautions are not taken. Of course, a government inspector can ensure that fences are built and warning signs put up, but vigilant neighbours will be the first to notice when they need repair or replacement or when sprinkler irrigation begins to encroach on land too close to their homes. The establishment of a residents' health committee can be a focus for a health education campaign, as well as providing a locally controlled institution to monitor the practice of wastes reuse.

Treatment (chemotherapy) of agricultural workers, their families and other exposed groups for intestinal helminth infections is relatively easy to administer in a formal wastewater irrigation scheme, although additional health personnel may be required to treat a large population. It can be quite popular, and provides an excellent opportunity for follow-up with hygiene education activities to publicize simple measures for personal protection. The cost of chemotherapy may be paid by the employers where salaried workers or share-croppers work the fields, or paid for out of the fees charged for irrigation permits where these are used.

Where wastewater is used on many small and scattered farms, there are greater logistic problems and the identification and treatment of exposed persons may become quite expensive. An additional problem arises where the wastewater is used illegally, as farmers may be unwilling to come forward, fearing prosecution. It may be necessary to give them reassurance by proclaiming an amnesty and by using different health personnel for the chemotherapy programme from those responsible for enforcing the sanitary regulations.

Those living close to irrigated fields or ponds are likely to include farm workers and their families, who will be exposed to infection in several ways. It may be easier to include them all in a mass treatment campaign aimed at farm workers than to attempt to determine the employment status of each individual.

The identification of infected individuals for treatment can be costly and time-consuming. Where the prevalence of infection is relatively high, mass treatment of the whole exposed population may be worth while. Against this must be set the cost of unnecessary treatment of persons who are not infected. The choice between mass chemotherapy and selective chemotherapy of infected individuals therefore depends largely on the prevalence of infection and on the relative costs of detection and treatment of cases.

Costs

The choice of which of these options to implement must be based not only on their efficacy, but also on their cost. If the cost of those chosen for implementation is likely to exceed the economic benefit of using the wastes, it is important to consider whether less expensive measures might suffice, or whether it is worth while to use the wastes at all. In most cases, the benefits are likely to justify the costs, but some financial arrangement is needed to ensure that the costs are met from a suitable source. These aspects are considered in Section 8.4.

8.3 New schemes

8.3.1 Project identification

Upgrading of existing schemes should generally take priority over the development of new ones. Upgrading may be needed to improve agricultural or aquacultural yields or to reduce health risks. Attention should be paid not only to the technical improvements required (see Section 7.2.5), but also to the need for better management of schemes and to their improved operation and maintenance.

Ideally, new schemes should be identified and their relative priority established in the context of a national plan for wastewater and excreta use. However, opportunities for new schemes will often arise in connection with major wastewater construction projects, and these need not necessarily be rejected for lack of a national plan that includes them. On the contrary, the possibility of wastes reuse is always worth considering when drawing up plans for land use, housing development or waste management, and an assessment of prospects for waste reuse should be included in consultants' terms of reference.

On the other hand, new schemes should be viable, with a potentially good rate of agricultural or aquacultural return at minimal risk to health and at least cost. There should also be at least the potential for developing a satisfactory local institutional framework within which they can be properly planned, implemented and operated.

Outline planning should be done at the project identification stage. This involves determining the size and scope of the project, and needs data and preliminary decisions on the following aspects:

- available quantities and qualities of excreta/wastewater;
- land/pond area requirements;
- crops/fish to be grown;
- quality requirements for excreta/wastewater, and hence possible need for treatment;
- outline design for transportation of excreta/wastewater; storage requirements;
- preliminary selection of application techniques;
- institutional and organizational aspects;
- current legislation and regulations affecting the use of wastes;
- preliminary economic and financial justification for the projects, including details of the market for the product;
- project timetable;
- whether a pilot project is required.

The strategy to be adopted for health protection (see Section 7) should be an integral part of these considerations. Many of the policy aspects that apply to the improvement of an existing practice (see Section 8.2) should also be borne in mind when contemplating a new scheme. A preliminary environmental examination, and outline consideration of the principal environmental consequences of the project, are also advisable at this stage.

8.3.2 Pilot projects

A pilot project is particularly necessary in countries with little or no experience of the planned use of excreta or wastewater, or when the introduction of new techniques (for example, localized irrigation) is envisaged. 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. These questions are likely to include important technical and economic aspects, including the feasibility of the scheme itself, so that preliminary trials on a pilot scale will often be essential anyway. A pilot scheme can also help to identify any potential health risks and develop ways to control them.

Proposals to introduce agricultural or aquacultural use of wastes are often made in connection with new sanitation works, particularly new wastewater treatment plants, but a pilot project at a nearby existing plant may provide the necessary advance information.

In parts of the world where a new scheme is most likely to be economically viable, it is especially probable that human wastes are already being used in some way or other. It will be well worth while to study existing practice in the area, and possibly in neighbouring countries, before considering new projects. Indeed, a government should at least consider how to ensure that the current practices are not hazardous to health before embarking on new developments in the sector.

From the agricultural (or aquacultural) point of view, a pilot project serves not only for experiment but also for demonstration. A representative selection of local or exotic crops should be made, and the experimental design should be a randomized complete block with at least three replications.

In the case of irrigation with treated wastewater or settled nightsoil, freshwater controls both with and without supplementary inorganic fertilizers are required; the use of diluted wastewater or nightsoil may be required for nitrogen-sensitive crops if nitrogen concentrations are high. Composted or thermophilically digested excreta, if used, should be applied to the experimental plots before planting, as should trenched nightsoil. Aquacultural pilot projects should be similarly planned: new fish species or plant crops should be investigated, with different application rates of different wastes (for example, pond effluents, compost, latrine contents). Information is required not only on crop yields but also on microbiological contamination levels, uptake of heavy metals, and soil and groundwater effects.

A pilot project should operate for at least one growing season, or at least one year if both winter and summer crops are to be investigated. It must be very carefully planned so that the work involved is not underestimated and can be carried out correctly; otherwise, repetition in the following year is required. After the experimental period, a successful pilot project may be translated into a demonstration project with training facilities for local operators and farmers.

8.3.3 Project planning: technical aspects

Detailed planning for excreta and wastewater use schemes should follow the usual national procedures for agricultural and aquacultural project planning, supplemented as necessary by the requirements of external funding agencies. The following discussion is centred on the particular planning needs resulting from the fact that the project is for excreta and/or wastewater use and from the need for health protection measures. In other regards, planning requirements for excreta and wastewater use schemes are similar to those for irrigation and fertilization schemes that are not based on the use of human wastes.

A great deal of information needs to be collected, and many decisions must be taken to prepare a detailed plan for a new scheme. The main technical aspects that should be covered by the plan are listed in Box 8.7. Several of these aspects interact. For example: in an irrigation scheme the types of crops affect the seasonal pattern of irrigation and hence the storage requirements; forestry can benefit from irrigation with wastewater at times when it is not required for other crops, and so help to balance the demand.

For each scheme, the planner should seek to maximize the net annual benefit from crop production in a manner consistent with labour constraints and the need to protect health and minimize costs. For this purpose it will be necessary to make cost estimates for the various activities, including major construction works for storage, treatment or transport of wastes, land preparation and irrigation infrastructure, and also for staffing, treatment, pumping and maintenance as well as other agricultural inputs.

An assessment of the benefits requires a forecast not only of the probable yields of the crops to be grown but also of their anticipated prices. This in turn demands a survey to establish that an adequate market exists for these crops. This is particularly important where crop restriction is to be employed as a health protection measure, and where the crops to be grown require industrial processing; in the latter case, sufficient processing capacity must be available.

Projects for the reuse of wastes are not static; they take time to be implemented and thereafter to evolve and grow. The plan should allow reasonable time-scales for all its aspects: to obtain funding, to execute any necessary construction works and to prepare the ground for the scheme to begin. From then onwards it should envisage the configuration of the project in each year of its future existence. For irrigation projects, a 20-year planning horizon is often considered.

Box 8.7 Technical information to be included in a project plan

Wastewater irrigation

- Current and predicted wastewater generation rates; current and predicted proportions of industrial effluents; degree of dilution by surface water.
- Existing and required wastewater treatment facilities; pathogen removal efficiencies, physicochemical quality.
- Irrigable land area: extent, location, type (virgin land, existing farmland, public parks); soil types, drainage, ground slopes (maps are needed).
- Local geology and potential risk of groundwater pollution.
- Conveyance of wastewater to the fields; pumping stations.
- Wastewater storage requirements, based on possible need to restrict irrigation to daytime or night-time, to utilize excess wastewater from a season that does not require it (for example, the rainy season), or to keep wastewater from one season to another to permit the production of more valuable or export crops, or crops that require greater wastewater treatment; or arrangements for wastewater disposal (if only dry-season irrigation is envisaged).
- Wastewater application methods for both restricted and unrestricted irrigation.
- Disposal of drainage waters, or their use to irrigate salt-resistant crops.
- Mix of crops to be irrigated; treatment implications of their wastewater quality requirements; if different qualities are required, how this can be achieved (for example, facultative pond effluent might be used for restricted irrigation, and maturation pond effluent for unrestricted irrigation).
- Crop water and supplementary nutrient requirements; crop nitrogen and boron sensitivities; soil leaching requirements.
- Estimated crop yields per hectare.
- Overall strategy for health protection.

(Box 8.7 continued)

Agricultural fertilization with excreta

- Current and predicted excreta/sludge generation rates.
- Existing and required treatment facilities; pathogen removal efficiencies, physicochemical quality.
- Fertilizable land area: extent, location, soil types.
- Conveyance of treated or raw excreta/sludge to the fields (collection by farmers or delivery by treatment authority).
- Excreta/sludge storage requirements.
- Excreta/sludge application rates and methods.
- Mix of crops to be fertilized, and their requirements for excreta/sludge quality, supplementary nutrients and water; treatment implications.
- Estimated crop yields per hectare.
- Strategy for health protection.

Aquacultural use of excreta and wastewater

- Current and projected generation rates of the wastes (excreta, sludge or wastewater); proportion of industrial effluents; dilution by surface water.
- Existing and required waste treatment facilities; pathogen removal efficiencies, physicochemical quality.
- Existing and required pond areas: size, location, soil types (lining requirements); depuration pond requirements.
- Evaporation (need for make-up water).
- Conveyance of treated wastes to ponds (collection of treated excreta and sludge by farmers or delivery by treatment authority).
- Storage requirements for the wastes.
- Waste application rates and methods.

(Box 8.7 continued)

- **Types of fish and aquatic plants to be cultured, and their requirements for wastes quality and supplementary nutrients.**
- **Estimated yields of fish or plants per hectare of pond per year.**
- **Feasibility of rearing ducks on the ponds; feeding requirements.**
- **Strategy for health protection.**

It will often be advisable to allow for a modest beginning, followed by a phased expansion of the project in subsequent years (see Box 8.8). This will allow time to train farmers and staff in new methods and for lessons learnt in the early stages to influence later developments. It will also help to ensure that the level of production does not over-reach the current availability of the waste or the demand for the crops produced.

Projects using wastewater will be affected by a progressive change not only in the quantity of wastewater available but also in its quality. As the number of people served by the sewerage network increases, this will lead to increased wastewater flows, to reduced dilution by storm water and by ground water infiltrating into sewers, and also to reduced retention times in wastewater treatment works. Where a new sewerage network has been built, the proportion of the population having connections to it may initially be very low indeed, and allowance for this should be made in the project plan.

Multiple use of wastes

The feasibility of integrated schemes making multiple use of wastes should also be considered, as this will often lead to reduced costs. For example: when wastewater from a series of stabilization ponds is used for irrigation, fish may be reared in the third and subsequent ponds in the series; excreta and sludge treatment facilities can often be located at a wastewater treatment works, and the treated product applied to the same fields that are irrigated with treated wastewater (although care must be taken not to overload the system with nutrients, especially nitrogen); aquaculture pond effluents may be used for crop irrigation. Biogas generation can also be linked to other uses for wastes, if there is a local demand for the gas.

Box 8.8 Wastewater irrigation in Kuwait

Wastewater irrigation in Kuwait started on a limited scale in the mid-1970s, with alfalfa grown as the main crop to feed cattle for the dairy industry. On the basis of the experience gained, the first phase of expansion was commissioned ten years later, bringing the total farm area to over 1700 ha. Garlic and onions will also be grown, like the alfalfa, under sprinkler irrigation. Aubergines and peppers will be irrigated using flood and furrow techniques.

The scheme will be further extended as the available quantity of treated wastewater increases. It aims to make Kuwait self-sufficient in milk, potatoes, onions and garlic by the year 2010. In addition, an ambitious afforestation programme is planned, to provide wind and dust breaks along major highways and to protect new townships.

All areas where wastewater is applied are fenced off to prevent public access, and farm workers are to be subjected to regular health checks. One factor permitting the efficient organization of the health protection strategy and of the project as a whole is that the farm is managed by a single company, which is supplied with treated wastewater by the Ministry of Public Works.

Source: Cowan & Johnson (1985).

8.3.4 Project planning: institutional aspects

A detailed discussion on the organization of irrigation schemes is given in a recent FAO publication (Sagardoy, 1982), and much of it is applicable to the organization of schemes for the agricultural use of excreta and the aquacultural use of excreta and wastewater. The following discussion focuses on those aspects particularly relevant to such schemes.

To a substantial degree the organizational pattern of a wastes reuse scheme will be determined by the established land use pattern and existing institutions. Health protection measures are easier to implement effectively when the scheme is run as a single unit, whether by a private company, by a cooperative or by a public body (see Box 8.8). However, where the land involved is already farmed by smallholders, it will usually be unavoidable that they should continue to farm it when the use of wastes is introduced. In this case, some form of users' association and a joint management board would be almost essential for the implementation of those health protection measures that require their cooperation.

It may also be necessary to give the smallholders some security of tenure of the land and of their right to the wastewater in appropriate quantities and at appropriate times, especially if they are to be required to invest more cash or to change to crops that take longer to mature. This may be difficult when the owners of the land have bought it for speculative purposes, and when urban expansion has already pushed up the price of land on the periphery to very high levels.

Large schemes (greater than about 200 ha or with more than 500 farm units) need a full-time professional staff to manage them, and can afford to pay for it out of land rents, water charges or, where this management staff also runs the farm and employs those who work on it, from the sale of produce.

The body that manages the scheme, either by running it as a plantation or by distributing wastewater to individual farmers, is often distinct from the sanitation agency responsible for collecting and treating the wastewater. This may enable it to relate more closely to the Ministry of Agriculture or of Water Resources and may give it greater freedom of action, which can be advantageous given the uncertainties of weather and agricultural prices; on the other hand, its lack of control over treatment means that it is dependent on good relations with another agency for the reliable implementation of what is usually the principal measure for health protection.

In some of the most efficient schemes (for instance, at Werribee, Australia—see Section 3.1.1), the whole operation, from collection of the wastewater, through its treatment and application, to the sale of the crop or livestock, is run by a single agency. Where this is not possible, some local arrangement for intersectoral coordination will be needed, as at national or regional level (see Section 8.1.2). It is particularly important that the areas of responsibility of each relevant agency should be clearly defined.

A common measure, particularly in schemes using wastewater from a public sewerage network, is to issue permits for the use of the resource. These are usually issued by the local agriculture or water resources administration, or by the body controlling the wastewater distribution system. Provision for such permits is often made in the existing water resources legislation to control abstraction, but when wastes are to be used the issuing and renewal of a permit can be made conditional on the observance of sanitary practices regarding application methods, crop restriction and exposure control. A permit system can also be applied to the use of excreta, especially where the excreta is collected by a municipal body, and to aquaculture.

It is also common for the body administering the distribution of wastewater to deal with the farmers or pond owners through users' associations, which will often develop from traditional institutions.

Permits to use the wastes can then be issued to the associations, which simplifies the administrative task of dealing separately with a large number of small users and also delegates to the associations the task of enforcing the regulations which 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 any particularly large users, the authorities that collect and distribute the wastes, and also the local health authorities, is another institution which has proved its worth in many schemes, for example in Calcutta (see Box 8.9). Even in small-scale organizations, some arrangement such as a committee with community representatives is essential for the users to participate in the management of the project.

Box 8.9 Management of wastewater use in Calcutta

Wastewater from Calcutta is conveyed to the wetlands east of the city through two main canals, from which it passes into a complex system of secondary and tertiary channels. From these, a regulated amount is fed into an extensive system of ponds through simple gates; the fishermen have learned over the years how to judge the amount needed by taste, smell and sight.

There are some 160 owners of ponds in the area, most of whom are absentee landlords working through resident managers. Each employs from 50 to 200 fishermen, mostly on a seasonal basis, and owns up to 400 ha. Some have leased the land from the Calcutta city authorities, and there are also three fishermen's cooperatives with their own ponds. Altogether about 4000 families live by fishing in some 5000 ha of pond area.

Some of the wastewater is used to irrigate vegetables grown on the nearby garbage dump where some 2000 families farm 1400 ha. Lease of this land was granted in 1879 by the city authorities but is currently under dispute; a three-tier pattern of ownership now exists, with lessees letting out the garbage gardens to tenants who in turn receive payment from farm workers.

Further downstream, wastewater treated in the pond system is used to irrigate approximately 6500 ha of paddy fields, from which 5000 families earn all or part of their income.

A joint committee, comprising pond-owners, downstream landowners and Calcutta city authorities, has recently been set up to deal with problems of common concern such as irregularities in the supply of sewage and theft of fish by armed gangs!

Source: Strauss (1986d).

Further details of wastewater use in Calcutta are given in Section 3.

Support services

Various support services to farmers are particularly relevant to the implementation of health protection measures, and detailed consideration should be given to them at the planning stage. They include the following:

- farm machinery (sales and servicing, or hire);
- supply of supplementary fertilizers, irrigation pipe, protective clothing, etc.;
- agricultural credit;
- agricultural extension and training;
- marketing services, especially where new crops are to be introduced or new land brought into productive use;
- primary health care, possibly including regular health checks for field workers and their families (see Section 7.5).

Training

Training requirements must be carefully evaluated at the planning stage, and it may often be necessary to start training programmes, especially for farmers and operators, before the project begins, in order to ensure that an adequately trained cadre is available when needed. Plant operators require on-the-job training in all aspects of the operation of treatment plant, delivery systems and pumping stations, farmers will need training in agronomic methods most suitable for excreta and wastewater use, and technicians will require training in sample collection and analysis.

Similarly the likely need for agricultural and aquacultural extension services must be estimated, and provision made for them to be available to farmers after implementation of the project. Extension officers will themselves need training in the farming methods appropriate to health protection, as will the staff responsible for enforcing sanitary regulations regarding crop restriction, occupational health, food hygiene, etc.

Such training requirements are best met by local technical colleges and universities, but many countries may lack the specific expertise needed; overseas training may then be the only alternative in the short term until sufficient in-country experience is developed. This is an area in which cooperation between neighbouring countries can be especially fruitful.

8.3.5 Legislation

If new projects for the use of wastewater or excreta for agriculture or aquaculture are to be introduced or promoted, legislative action may be needed. In many cases it may be sufficient to amend existing regulations, but sometimes new legislation is required. 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 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.

These are discussed in turn.

Creation of new institutions

Enabling legislation may be required to establish a national coordinating body for the sector (see Section 8.1.2) and to set up local bodies to manage individual schemes. These will require a certain degree of autonomy from central government and the ability either to charge for the wastes they distribute or to sell any crops they produce.

National and local government

The local body managing a scheme, or at least the agency collecting the wastes, will often be under municipal control. If new schemes are to be promoted in the context of a national policy, this implies careful coordination and definition of the relationship between local and national government. On the one hand, it may be necessary for the national government to offer incentives to local authorities to promote new schemes, but at the same time, sanctions of some sort may have to be applied to ensure that schemes are implemented without undue risk to public health.

Incentives may take the form of grants, low-interest loans or technical assistance for the establishment of new schemes. Another incentive, with possible application in arid areas, is to offer increased rights of abstraction of surface or ground water for water supply development to municipalities that develop wastewater irrigation (see Box 8.10). Sanctions might be needed to ensure compliance by municipal wastewater treatment works with national wastewater quality standards; if no such legislation exists, consideration should be given to enacting it in the broader context of environmental pollution control.

Rights of access

Farmers will be reluctant to install irrigation infrastructure, to build fish-ponds, etc. unless they have some confidence that they will continue to have access to the wastes. On the other hand, this access may be regulated by permits and dependent on efficient or sanitary practice by the farmer. In Mexico, the authorities' power to withhold water from farmers who do not comply with crop restrictions is a major factor in their success. In Chile, on the other hand, the water law vests water rights in the owners of the land, and the sanitary authorities have little leverage to impose much-needed restrictions (Bartone & Arlosoroff, 1987). Legislation may therefore be required to define the users' rights of access to the wastes and the powers of those entitled to allocate or regulate those rights.

Land tenure

Security of access to wastes is worth little without security of land tenure. Existing land tenure legislation is likely to be adequate for most eventualities, although it may be necessary to define the ownership of virgin land newly brought under cultivation. If it is decided to amalgamate individual farms under a single management, powers of compulsory purchase may be needed.

Public health

The area of public health includes rules governing crop restrictions and methods of application, as well as quality standards for treated

Box 8.10 Mexican national programme for wastewater use

The National Programme for the Use of Wastewater in Mexico is being set up to answer the increasing demand for water—by agriculture, industry and domestic users. The basis of the programme is that clean water, in areas where it is used for irrigation or in industry, can be 'exchanged' with wastewater, thereby releasing the clean water for domestic use while satisfying the water demands of agriculture and industry. In addition, using wastewater instead of disposing of it in rivers will reduce the level of environmental contamination and contribute to pollution control. The programme is currently in the planning stage, and final decisions on its execution have not yet been made.

At present, most of the untreated wastewater from large- and medium-sized cities is used for irrigation and six organized irrigation district units completely depend on this source of irrigation water. A total of 2400 million cubic metres of wastewater is used per year to irrigate 156 000 ha of land. It is planned to increase this to an annual 2600 million cubic metres of wastewater on 237 000 ha of land in 17 irrigation districts in 6 states. In this way, first-use water will be freed to supply the domestic and industrial water demand of 29 million inhabitants.

The planning of this programme will involve state and municipal governments, as well as industrial concerns, coordinated by the Ministry of Agriculture and Water Resources (SARH) which has the power to allocate water rights. It is likely that the sewage from each municipality will need some form of treatment before it can be used in agriculture. Regulations for the use of wastewater will be drawn up through coordination between SARH (including the Sub-Secretariat of Agriculture) and the Ministry of Urban Development and Ecology with the support of the World Health Organization. If the wastewater does not meet the regulations, SARH will demand that the municipality involved must treat it to the specified quality before it is 'exchanged' with the clean water. SARH will advise on the most appropriate type of treatment via a coordinated group of ministries, including the Ministry of Urban Development and Ecology and the Ministry of Health. Help with the finance needed to effect this treatment will be given by the Ministry of Urban Development and Ecology.

Source: H. Romero, personal communication.

wastewater and excreta used in agriculture or aquaculture, which may require an addition to existing regulations. It also covers other aspects of health protection, such as occupational health and food hygiene, which are unlikely to need any new measures. The risk of passing laws that are too stringent to be realistically complied with is just as significant with new schemes as in the case of an existing practice (see Section 8.2.2). The factors affecting the feasibility of enforcing crop restrictions, discussed in Section 8.2.3, are equally relevant to new schemes.

8.3.6 Public relations and information

The maintenance of good public relations, especially with respect to protection of consumer health, is a very important task. The public must have confidence that the produce they are consuming is in no way injurious to their health. Schemes for excreta and wastewater use must be seen by the public to be operated with due regard for their health, and assurances as to the quality of the food consumed and of the efficacy of excreta and wastewater treatment prior to land or pond application will do much to promote public acceptance of such schemes. In this respect, programmes for the routine monitoring of excreta and wastewater and of crop quality are extremely important, as is the demonstrated absence of the transmission of excreta-related disease (see Section 8.5).

The public should be kept informed about all schemes for excreta and wastewater use—whether agricultural or aquacultural, including tree and green space irrigation or land reclamation—so that they may fully appreciate governmental efforts to improve food supplies, safeguard health and protect the environment. The choice of communications media—for example newspapers, posters, radio—should be made with due regard to local customs and advertising practice, as it is important that public information campaigns about excreta and wastewater use produce the correct impact at reasonable cost.

The consumer need not be the only target of public information activity. Current and potential users of the waste and owners of (and workers in) the fields or ponds where wastes can be used must be informed of the potential for increased production and of the measures needed to safeguard health. Health education is essential where human exposure control is part of the health protection strategy. Promotional activity and health education are more effective when carried out through people in the community than through mass media. However, this requires a considerable number of dedicated staff, unless it can be achieved through an existing network of community workers.

8.4 Economic and financial considerations

Economic factors are especially important when the viability of a new scheme for the use of wastewater or excreta is being appraised, but even an economically worthwhile project can founder without careful financial planning. Economic appraisal considers whether a project is worth while, whereas financial planning looks at how projects are to be paid for. Improvements to existing practices must be paid for in some way and therefore also require some financial planning. The two areas are discussed in turn.

8.4.1 Economic appraisal

The economic appraisal of an excreta or wastewater use project is undertaken to determine the advisability, in relation to the country's economy, of proceeding with it (Squire & van der Tak, 1975; Gittinger, 1982), and thus seeks to answer the question of whether the country can afford it. This requires a calculation of the marginal costs and benefits of the project, that is, the differences between the costs and benefits of the project and the costs and benefits of the alternative. For a scheme to be viable, its marginal benefits must exceed its marginal costs.

Wastewater

The economic appraisal of wastewater irrigation schemes is complicated by the fact that the alternative—what would be done in the absence of the scheme—might be any of the following:

- no agriculture at all;
- no irrigation at all (that is, rain-fed agriculture);
- irrigation with water from an alternative source without fertilizer application; or
- irrigation with water from an alternative source with fertilizer application.

The marginal benefit accruing from wastewater irrigation is different in each case.

Where land is a scarce resource, the objective may be to obtain the maximum marginal benefit per hectare. In other cases, especially those where the alternative is no agriculture at all, the most significantly scarce resource is water, and the aim is to obtain the greatest benefit from every cubic metre of wastewater used. The appraisal of a specific project involves not only comparing it with all the appropriate alternatives but also comparing possible variants of the same scheme — for instance, the use of different irrigation methods or the production of different crops.

The cost of the wastewater includes the cost of any additional treatment required (to bring it to the Engelberg standard for instance), as well as the cost of conveying it to the field and applying it to the crop. However, it is essential to subtract from this the cost of the alternative arrangements for wastewater disposal which would be required if the project were not implemented. Thus, if the alternative would involve some treatment, only the cost of additional treatment would be included.

In many cases, the alternative involves expensive long-distance transport of wastes or sea outfalls, so that reuse may be the cheapest disposal option even before the value of agricultural production is included. This rationale justifies the use of wastewater to irrigate municipal parks and gardens, as in some cities in the Eastern Mediterranean area and the USA.

If the alternative is to be rain-fed agriculture or irrigation with fresh water from another source, the values of the alternative crop yields and the costs of any fertilizer used must be taken into account. One particular benefit of wastewater irrigation is the saving in the cost of abstracting fresh water from its source — especially when that fresh water might otherwise be valuable for such purposes as industrial and domestic supplies. Unfortunately, it is often the case that insufficient information is available to allow the full costs and benefits of the alternative to be calculated, and wastewater use must then be compared with the alternative of no irrigation at all or, more commonly, of no agriculture.

Economic appraisal recognizes that the real cost or value of an item to a country's economy is not always the same as the price paid for it. For example, foreign exchange may in fact be more valuable than the formal, controlled exchange rate would suggest. On the other hand, the labour of workers who would otherwise be unemployed costs less to the economy than their wages, since no production is lost elsewhere by offering them a job. Economists use a 'shadow price' to approximate the 'real' value of an item to the national economy. Thus the shadow price of foreign exchange is usually higher, and that of unskilled labour lower, than the rate actually paid for it.

The use of shadow prices is particularly important for the economic appraisal of wastewater use schemes, and tends to favour them for at least two reasons. First, the treatment process most appropriate for wastewater irrigation (stabilization ponds) can be built by labour-intensive methods and requires less imported equipment than other processes; at shadow prices, it is more likely to be cheaper. Second, the prices of many of the crops likely to be grown in a scheme (such as cereals, oilseeds and cotton) are often held below the world market price. Whether they are grown for export or for import substitution, a shadow price for foreign exchange will show their true value to the economy.

Excreta

Methods for the economic appraisal of excreta use schemes are less sophisticated than those for wastewater irrigation, since some of the benefits — such as improvement of the soil structure — are much more difficult to quantify. The alternative is taken to be one of no fertilization at all, and thus an excreta use scheme would be judged to be economically viable solely if the value of its resulting marginal benefit (increased crop yield) were greater than the cost of excreta treatment, conveyance and application.

Aquaculture

There are two possible alternatives for comparison:

- no aquaculture at all;
- aquaculture with an alternative source of pond fertilizer.

Economic appraisal is thus similar to that of wastewater irrigation, and a viable benefit-cost ratio implies that the marginal value of the fish or aquatic crops produced is greater than the cost of the treatment and conveyance of the excreta or wastewater used to produce them.

8.4.2 Financial planning

Charging for the resource

Where wastewater is distributed by a separate agency from that which collects and treats it, a charge of some sort is normally payable.

Charges are also levied when the waste is distributed to individual farmers.

The level of these charges must be decided at the planning stage (see Box 8.11). The Government must decide whether they should be set to cover only the operation and maintenance costs or set higher to recover the capital costs of the scheme as well. While it is of course desirable to ensure the maximum recovery of costs, an important consideration is to avoid discouraging the farmers from the permitted use of the wastes. Some prior investigation of farmers' willingness and ability to pay is therefore essential, not only in determining the level of charges but also the frequency, time and means of payment. For instance, an annual charge payable after the harvest season may be the easiest to collect.

Box 8.11 Wastewater reuse in Trujillo, Peru

Trujillo is a city of 400 000 inhabitants situated on the arid north-central coast of Peru. An existing sewer system serves almost 90% of the population, discharging directly on to the beach just to the north of the urbanized area. However, wastewater is extracted at several points for authorized sugar-cane or forage crop irrigation, and at several other points clandestine derivations are made by local farmers for food crop irrigation. In some cases, farmers have constructed rudimentary pond systems to treat the wastewater in order to obtain irrigation "permits", but these ponds are in fact nothing more than shallow anaerobic settling basins with retention times of about one day. The economic demand for irrigation water is great, as there is no rainfall throughout the year and a nearby river has streamflow for only five months of the year. Large areas of barren desert land that surround Trujillo could be put into agricultural production if water were available.

As part of a feasibility study done for the National Water and Sewerage Service with the financial support of the German agency Gesellschaft für Technische Zusammenarbeit, a planned effluent irrigation option was evaluated. It was found that of a total of 2100 ha suitable for irrigation, only 1300 ha could be irrigated throughout the year with the available wastewater volume (approximately 20.5 million cubic metres per year in 1990). By dividing the existing sewer system into micro-drainage areas it was possible to identify eight points in the system where wastewater could be diverted for gravity-fed irrigation after treatment in appropriately designed waste stabilization ponds. The chemical characteristics of the wastewater presented no problem for irrigation, so the principal concern was pathogen removal for which multicell ponds provide a good solution.

(Box 8.11 continued)

A financial analysis of the proposed reuse scheme with and without treatment showed that irrigation with treated wastewater would be feasible only if there was a fair allocation of the treatment costs between the principal beneficiaries — that is, between the municipality, which needs to dispose of its wastewaters in a sanitary manner, and the farmers who require irrigation water of adequate quality. The cost allocation formula recommended for Trujillo was to charge the construction costs to the municipality and the land costs and operation and maintenance costs to the farmers. A survey of local farmers found that they were agreeable to cost-sharing at this level in the form of either water tariffs or in-kind contributions of land and labour (a finding substantiated by the fact that some farmers were currently using ground water at about twice the cost allocated to them for treated wastewater). Using this formula, the reuse project is financially viable.

This example illustrates the fact that local farmers are often able and willing to pay for the effluents they use for irrigation, but that they should not be expected to subsidize the legitimate disposal costs of the municipality.

Source: Rojas et al. (1985).

It may be possible to develop an increased demand for the wastes by effective marketing, and this will often be worth while. However, the results of a marketing campaign should not be anticipated when setting the initial level of charges, which can be increased progressively as demand is developed.

On the other hand, farmers may sometimes be willing to share in the investment in treatment works that are a prerequisite to obtaining reuse permits. Their contribution may be in cash or in the form of land for treatment or storage facilities. Moreover, experiences in Peru have indicated that farmers may sometimes be willing to perform operational and maintenance tasks associated with treatment, storage and conveyance of wastes, as a contribution in kind to the running costs of the scheme (Bartone & Arlosoroff, 1987).

A farmer will pay for wastewater to irrigate crops only if its cost is less than that of the cheapest alternative water and the value of the nutrients that it contains. How then is the cost of the wastewater determined by the agency that sells it to the farmer? There are three basic approaches to establishing the price of wastewater. It can be related to:

- its production costs (additional treatment and conveyance);
- the benefits derived from irrigation; or
- some value judgement based on the farmers' ability or willingness to pay.

If the first option is selected, it should carry the proviso that costs must be no greater than that of the cheapest alternative source of water available to the farmers (usually ground water). The nutrient value of the wastewater may be included or ignored.

In the case of aquaculture and the use of excreta in agriculture, the price for the excreta or wastewater is usually based either on the marginal cost of treatment and conveyance or on the value of the nutrient (usually nitrogen) content, whichever is lower. There are several possible ways of charging for the waste, such as:

- per cubic metre (or, for excreta, per ton);
- per hour of discharge from a standard sluice;
- per hectare of irrigated or fertilized land.

It can also be paid in various ways:

- as a specific water rate or purchase price;
- as a renewal fee for an abstraction permit;
- as a surcharge on the land rent;
- as a deduction from the price of centrally marketed crops.

A particular problem needing prior consideration is the question of liability and the action to be taken when, for one reason or another (for example, because of a breakdown in the treatment works), the wastes do not meet the agreed quality requirements. It will be difficult to prevent farmers from using the wastes, particularly if this happens at a time of peak demand when the lack of water or fertilizer could seriously prejudice plant growth. The simplest solution is probably to exempt the farmers from charges for the period when the wastes fail to meet the quality standard. They should of course be informed of the problem and the health risks involved, and every possible temporary measure should be taken to keep those risks to a minimum until normal quality is restored.

Payment for health protection

It is not always appropriate or feasible to meet the cost of health protection by charging for the use of the wastes. Financial considerations regarding each of the four types of health protection measure are discussed below.

(a) Treatment

Wastewater. Wastewater treatment works are expensive to build; the heavy capital investment required exceeds the resources of most municipalities in developing countries, so it is usually met, together with the cost of the sewerage system, by grants or loans from central government. The operating costs, on the other hand, can usually be met from a municipal tax or water tariff. The costs of treatment are usually justified on grounds of environmental pollution control.

However, the treatment of wastewater to a standard of quality adequate for use in agriculture may involve additional costs for construction and maintenance. Some of these additional costs can be met by the sale of the treated wastewater or the fee for the permit allowing its use. In practice, however, the prices charged for the wastewater and the fees levied for permits are often determined by what farmers are prepared to pay. In such cases, the difference may be considered as a government subsidy to the farmers to promote the use of the wastewater. It is common in practice for irrigation water to be supplied to farmers at subsidized rates.

Excreta. The capital cost of nightsoil treatment can be very modest and part, at least, of the treatment cost can be recovered from the sale of the treated nightsoil. It is likely to consist largely of recurrent operating costs and to be relatively small in comparison with the cost of collecting the raw excreta. If the market value of the treated product is low, the balance of the treatment cost can be met from the same budget that supports the nightsoil collection service. This may even represent a saving in relation to the greater alternative cost of disposing of the untreated excreta. When the excreta are composted together with domestic refuse, the saving in the cost of disposing of solid waste can be considerable.

If individual farmers are to be encouraged to treat nightsoil or wastewater, for instance by building a nightsoil storage tank or — in the case of aquaculture — by separating off part of a fish-pond, they may need credit to help them with the capital cost of any construction required. An existing agricultural credit system can be used to implement this, if it can give specific priority to farmers using wastes.

(b) Crop restriction

The demands of crop restriction for the purpose of health protection often run against the incentives of the market; salad vegetables, for example, are often more profitable than industrial crops. A farmer who complies with crop restriction regulations that prohibit salad crops will thus make less money than one who disobeys them. The difference in profit is the cost of compliance. To some extent this cost is a result of market distortions, because the prices of the crops carrying a smaller health risk (such as cotton, grains and oilseeds) are often kept artificially low by the government or by marketing boards. At uncontrolled prices, such as the world market prices, some of these crops might be almost as profitable as the crops forbidden by the regulations. Their production may be as valuable to the national economy, although the farmer is paid less for them. In these circumstances, it would be perfectly rational for the government to subsidize the use of wastes, subject to crop restrictions, as a correction to the price distortion.

However, it is not usually feasible to pay this subsidy in the form of a higher price for the permitted crops. A two-tier price system (a subsidized price for the crop when grown using wastes, and a lower price otherwise) would be open to abuse; on the other hand it is not a simple matter to remove existing price distortions that affect the country as a whole. The subsidy can be paid more easily in the form of government support for other measures, particularly health protection measures involving treatment and application of wastes and human exposure control.

Nevertheless, these other forms of subsidy will not remove a price incentive to the farmer to disobey crop restrictions. The regulations have to be enforced, and this also costs money. The enforcement is normally carried out by the body that issues permits to use the wastes (often the Ministry of Agriculture) or by local staff of the Ministry of Health. In either case, enforcement of crop restrictions is only one of many tasks performed by the staff responsible, so the cost is usually included in the budget that supports their salaries, transport, etc. However, this is not an excuse for neglecting the cost of establishing an efficient enforcement system. Crop restriction may mean that less need be spent on treatment, but it will not be effective if adequate financial provision is not made for its enforcement.

(c) Application

Sprinkler irrigation, which potentially causes more widespread contamination with wastewater than other methods, generally requires less preparation of the land than surface irrigation. If surface or subsurface irrigation is chosen to minimize this contamination, the land can often be prepared more easily and cheaply by a central organization than by individual farmers. Alternatively, farmers can be assisted with the loan or hire of the necessary equipment. Since preparation of the fields helps the farmers avoid other expenditure, the cost can be recovered from them in the same way as other irrigation costs—through land rent, water charges or permit fees. Since localized irrigation uses less water and can produce higher yields, farmers themselves may find it worth while to change to this method.

(d) Human exposure control

The purchase of protective clothing will normally be at the expense of the workers who wear it or of their employers.

It might be possible for the cost of regular treatment for intestinal helminths to be charged to large employers, for example by a surcharge on the fees they pay for a permit to use wastewater. However, if the treatment is carried out by the national health service, the procedure for reimbursing the Health Ministry for the cost of the treatment from a fee paid to another body may be complicated. It is not advisable to charge the farmers for the treatment, as chemotherapy should be free if full coverage is to be attained. The cost is therefore likely to be most conveniently borne by the normal budget of the health service.

8.5 Monitoring and evaluation

The combination of health protection measures adopted in a particular wastes reuse scheme is a complex system that requires regular monitoring to ensure that it continues to function effectively. Monitoring, however, in the sense of observing, inspecting and collecting samples for analysis, is not sufficient on its own. Institutional arrangements must be made for the information collected in this way to provide feedback to those who implement the health protection measures. In other words, answers must be provided in advance to the following questions:

(a) What information will be collected?

(b) How often and by whom?

(c) To whom will this monitoring information be given?

(d) What decisions will be taken on the basis of the monitoring information?

(e) What powers will exist to ensure that those decisions are implemented?

To answer question (d) requires a set of guidelines or standards with which the monitoring results can be compared. There are two types of answer to question (e). First, in the case of monitoring by an operating agency (for instance a municipal sewerage board), those who interpret the monitoring information can simply give orders to their subordinates to take any corrective action needed. Second, in the case of surveillance by an enforcement agency (for instance a Ministry of Health), the agency has legal powers to enforce compliance with quality standards and other legislation. A complete monitoring and control system therefore needs:

- guidelines or standards;
- monitoring or surveillance to assess compliance;
- institutional arrangements for feedback or enforcement.

The responsibility for the monitoring of health protection measures must be clearly defined at the outset if it is not to be neglected. Appropriate aspects for regular monitoring and evaluation include the following:

- implementation of the measures themselves;

- microbiological quality of the wastes;
- microbiological quality of the crops;
- surveillance of disease in exposed groups.

Implementation of the measures

The principal health protection measure in many cases will be treatment of the wastes to adequate standards of quality (see below). The implementation of the other measures can be monitored by surveys as described for existing practices in Section 8.2.1. These need to be conducted at more frequent intervals during the first months of operation of a new scheme, but the frequency can be progressively reduced to once or twice a year once any initial problems have been ironed out.

Wastes quality

With regard to wastes treatment, it may be more fruitful to monitor the functioning of the treatment system than to take frequent samples of the treated waste for microbiological analysis, which can be difficult, time-consuming and expensive. Monitoring of the hydraulic loading on a set of stabilization ponds, for instance, is relatively easy and can immediately explain any deterioration in effluent quality which would be inexplicable on the basis of microbiological data alone.

In particular, the Engelberg guideline values are not intended as standards for quality surveillance but as design goals to be used when planning a treatment system.

Nevertheless, the agency responsible for the operation of the larger nightsoil or wastewater treatment works should carry out a regular check on the microbiological quality of the treated wastes, at least for faecal coliforms. In many cases, however, the only body with the necessary laboratory facilities for a full microbiological examination is the Ministry of Health or the local health administration. Whether or not it carries out the laboratory tests for the wastes treatment agency, the Health Ministry is usually best placed to maintain overall surveillance of the quality of wastes used in agriculture and aquaculture. For surveillance purposes, the samples for examination should be collected, as well as examined, by the government department responsible, to ensure that the results are interpreted in true perspective.

Since intestinal nematodes are a major health risk, and their eggs are more persistent than faecal bacteria, it would be ideal if the laboratory examination were to include a test for the concentration of intestinal nematode eggs. However, the laboratory techniques involved are still at an experimental stage.

Samples should be collected under aseptic procedures and examined within 6 hours of collection. Between collection and bacteriological examination they should be kept at about 4 °C, for instance on ice in an insulated coolbox. Where the effluent has been disinfected with chlorine, samples should be dechlorinated immediately and special care taken to prevent the regrowth of bacteria. Field testing will be more appropriate in many cases than transportation to a laboratory. Samples should preferably be collected by staff of the laboratory where they will be examined. If this is not possible, particular attention must be paid to proper sample identification and presentation; details of bacteriological test procedures are given elsewhere (American Public Health Association, 1985). A simplified procedure for faecal coliform bacteria is described in Box 8.12.

A procedure for enumerating nematode eggs in wastewater samples is given in Box 8.13; for excreta samples the formol-saline-ether method may be used (Cheesbrough & McArthur, 1976). Note that nematode eggs are usually removed but not killed by sedimentation in wastewater treatment, whereas in the treatment of excreta they are usually killed but not removed. Thus in wastewater examination it is not necessary to ascertain whether the eggs are viable, whereas this is the primary concern when examining samples of excreta.

Samples of treated excreta and wastewater should be taken at least monthly for physicochemical analyses — pH, electrical conductivity, sodium adsorption ratio, nutrients (N, P, K) and boron — although this frequency may be relaxed if experience shows that the quality variation is small. Heavy metals should be included in the analysis if the wastewater contains a significant proportion of industrial waste.

Large excreta or wastewater use schemes may warrant the establishment of their own laboratory facilities for these analyses, but existing laboratories will generally be used. Local hospitals usually have facilities for microbiological analyses, and the chemical analyses may be done at local wastewater treatment works, schools or colleges, although for some analyses samples may need to be sent to a central laboratory (for example, the Laboratory of the Government Chemist or equivalent). However, lack of local laboratory capacity for quality monitoring is not an adequate reason for failing to make use of wastes.

Box 8.12 Simplified analysis for faecal coliforms

This procedure tests whether or not wastewater meets the Engelberg guideline of 1000 faecal coliforms per 100 ml for unrestricted irrigation.

Use normal aseptic procedures throughout. Prepare a 1 in 10 dilution by adding 1 ml of the wastewater sample to 9 ml of 8.5 g/l (0.85%) sodium chloride solution. Add 1 ml of diluted sample to each of 5 tubes containing 5 ml of A-1 medium[a] and a Durham tube. Incubate at 44.5°C for 19–23 h. Count the number of positive tubes (those showing gas production), and read the most probable number (MPN) of faecal coliforms per 100 ml of wastewater from the following table.

Number of positive tubes	MPN of faecal coliforms per 100 ml
0	<220
1	220
2	510
3	920
4	1600
5	>1600

Use the same procedure for samples of treated nightsoil. Shake the sample thoroughly and add 1 ml (or 1 g) to a screwcapped bottle containing 9 ml of diluent and a few glass beads. Shake the diluted sample thoroughly before adding to the tubes of A-1 medium.

[a] Composition: lactose, 5 g; tryptone, 20 g; NaCl, 5 g; Triton X-100, 1 ml; distilled water, 1 litre (American Public Health Association, 1985).

Crop quality

Monitoring of the microbiological quality of crops is also likely to be the responsibility of the Ministry of Health in its role as enforcer of the existing public health regulations. Where fodder crops are involved, this task will include the inspection for beef and pork tapeworm of the carcasses of animals fed with (or grazed on) these crops. Inspection should cover *all* carcasses and not just a sample. All infected carcasses should be rejected.

Box 8.13 Quantitative determination of helminth eggs in wastewater

This method, adapted from Teichmann (1986), relies on centrifugal flotation.

Procedure

1. Grab-samples of at least 1 litre of wastewater should be taken at a fixed time of day for each site and transported to the laboratory.

2. In the laboratory each sample is placed in a 1-litre beaker (15 cm diameter) and allowed to settle for 8 hours. Sedimentation can occur overnight and the procedure be continued the next day.

3. After sedimentation the supernatant is removed by using a water jet (vacuum) pump.

4. The sediment is transferred into 20-ml centrifuge tubes (maximum 3 ml per tube). The walls of the sedimentation beaker should be cleaned thoroughly using a spray bottle and the rinsing water added to the sediments in the centrifuge tubes. They are then centrifuged for 10 minutes at 700*g* and the supernatants are discarded.

5. 3 ml of $NaNO_3$ solution (500 g/l) are added to the sediment in each tube. The sodium nitrate solution should have a relative density of 1.3 (*Note*: if the relative density is too low, the centrifugal flotation will not work properly and some eggs will not float to the surface).

6. After adding $NaNO_3$, the tubes are centrifuged for 3 minutes at 1000*g*.

7. The supernatant (now containing the helminth eggs) is removed carefully and kept in a 1-litre beaker (15 cm diameter) containing just less than 1 litre of pure water. (The water dilutes the sodium nitrate so that the eggs will settle to the bottom of the beaker.)

8. 3 ml of $NaNO_3$ solution are again added to the sediment in each tube, and the tubes are centrifuged at 1000*g* for 3 minutes. The supernatant is carefully removed and added to the 1-litre beaker containing the first supernatant.

9. The procedure in (8) is repeated (so that the sediment is centrifuged with sodium nitrate a total of three times).

(Box 8.13 continued)

10. The beaker containing all the supernatants diluted in water is left for several hours, to allow all the helminth eggs to settle to the bottom.

11. The supernatant from this beaker is carefully removed and discarded, and the sediment is transferred to centrifuge tubes. The walls of the sedimentation beaker should be cleaned thoroughly using a spray bottle, and the rinsing water added to the sediment in the centrifuge tubes. The tubes are then centrifuged for 4 minutes at 1000*g*.

12. The final centrifugate is placed on slides and examined under the microscope. It can be brightened up with paraffin oil after evaporation of the water. Helminth egg counts are made under × 100 magnification.

Variants

- Instead of collecting all the supernatants from the sodium nitrate centrifugation in a beaker of water for resedimentation, the supernatants from all three centrifugations (steps 6 to 9) can be filtered through a membrane filter (pore diameter approximately 10 μm). The filters can be air-dried in neutral balm embedded on slides or they can be viewed directly and egg counts made. Use of membrane filtration is probably simpler and more efficient, but also more costly, than the above procedure.

- In steps 2 and 7, the 1-litre beaker can be replaced by a 1-litre conical flask. This will encourage sedimentation and may produce a higher recovery rate of eggs. Use of several smaller conical containers (such as urine flasks) could be considered.

- If sodium nitrate is not available, magnesium sulfate of a similar relative density could be tried. The percentage recovery with $MgSO_4$ has, however, not been assessed.

Recovery rate

Using this procedure, recovery is about 70%, when egg density is 100 per litre. When the egg density decreases, the recovery rate also decreases. At 10 eggs per litre, recovery is about 50% and at 1 egg per litre it is further reduced to 33%.

Disease surveillance

Disease surveillance should focus first upon farm workers, who are the group most likely to be exposed to infection as a result of using wastewater or excreta. The simplest form of surveillance, and therefore the minimum for any waste reuse scheme, is a regular stool survey of a sample of workers for intestinal parasites. This is best carried out at a fixed time of year, because of the tendency to seasonal variation in the prevalence and intensity of infection with several of these parasites. If chemotherapy is administered, a survey can conveniently be carried out just before the annual round of treatment.

Surveillance of diarrhoeal diseases poses greater difficulties; it should preferably concentrate on individual pathogens, although this is not easy. Bacteriological examination of stools is expensive and may not give very consistent results. However, where typhoid is endemic, a serological survey using the Widal test (Cheesbrough & McArthur, 1976) would be relatively easy to carry out at the same time as the collection of stool samples for the parasitological survey.

The epidemiological considerations (sample size, ethics, interpretation of results and so on) that are relevant to disease surveillance are very similar to those that should govern an epidemiological survey (see Box 8.3). An epidemiologist and a statistician should be involved in planning the surveillance programme, and should also be consulted if any apparent excess disease is detected among exposed groups of people.