3

The Risks of Excreta to Public Health

THE DISCUSSION has dwelled at length on the survival of pathogenic organisms in excreta, on which there is a good deal of information. This is the main health-related concern of the engineer when he is designing sanitary facilities. The planner and economist have a greater interest in epidemiological risk: if, in a given situation specific changes in excreta disposal are made, how much less disease will there be? This question can be rephrased in two ways, the first of which can be answered readily and the other only with the greatest difficulty. The easier question is: what are the disease problems associated with excreta, and thus, by implication, with inadequate excreta disposal facilities or inadequate personal or domestic cleanliness? The difficult question concerns the health benefits of improved sanitation: how much disease will be eradicated if a given sanitary improvement is undertaken? These questions are considered in general terms in this chapter.

Illustrative Sketches

The effects of the diseases accompanying unsafe excreta disposal are dramatized in the sketches of two imaginary settings that follow. Formal case studies of sanitation and health are then outlined before a discussion of the benefits of sanitation improvements.

A Southeast Asian family

In areas of Southeast Asia with high rainfall, a perennially hot climate, and a main cereal crop of irrigated rice, the diverse health hazards from excreta are illustrated by the following case history, a composite of several real sites and people. A family lives in a palm-roofed, wooden house surrounded by rice paddies and small irrigation channels, one of which, flowing near the house, acts as the domestic water supply. There are four children in the family: the mother has had six babies, one of whom died at the age of 15 months after a sudden attack of diarrhea; a school-age child died in a cholera epidemic that swept the region 4 years ago.

It is particularly difficult to control excreta in this damp environment—most feces are deposited close to the house, and the younger children urinate in the nearby canals. Several years ago a government campaign to provide pit latrines was mounted, and one was dug near the family's house. They used it for a while, until the pit flooded over in the monsoon season and a large quantity of fecal material was spread around the house. It was during the flooding that the cholera epidemic occurred; its sad consequences for the family, together with the unpleasant mess from the latrine, discouraged further use of the facility. The next government recommended that a concrete aquaprivy be built above the ground to avoid the floods, but the family could not afford this and returned to defecating close to the house during the day. Nocturnal excreta were collected in a bucket and deposited in a nearby fishpond.

How does this situation affect the family's health? All the children get diarrhea several times a year, the parents less regularly. The worst occasion was when two of the girls got it at the same time. The younger one, 15 months old, seemed to wither overnight, and she died the next day. Death was from rotavirus infection. (Why it is more often lethal in the tropics than in temperate countries is unclear: perhaps the poor sanitary facilities in this case gave the child an overwhelming dose of the virus; perhaps malnutrition, ubiquitous during the weaning period in communities such as this one, complicated the attack?) Most of the diarrheas are watery, sudden attacks, but last year the grandmother who shares the house with the family, was one of several people in the village who came down with a more painful diarrhea with bloody stools, from which she nearly died. Medicine from the dispensary four miles away helped initially, but she remained ill for weeks. This attack was from bacillary dysentery (shigellosis), though to distinguish it from amebiasis would have required laboratory diagnosis.

All these illnesses were dramatic, but the family has several health problems of which they are barely aware. The eldest son has not grown properly: although he is 23, he looks as if he were in his early teens; his belly is always grossly swollen, and the dispensary attendant can feel his hard liver and spleen under the taut skin of his abdomen. His condition is caused by schistosomiasis, which is spread from one person to another by a tiny snail living in the damp grass beside the canals and in the water itself. Several members of the family are infected, but only this boy shows signs of the disease.

In this region of paddies and canals, fish—sometimes cooked, sometimes pickled raw in vinegar—is an acceptable and available food. A portion of the fish consumed is from ponds fertilized with human feces, and this practice has caused some of the family to be infected by the liver fluke *Clonorchis sinensis*. Another helminth that the family harbors in large numbers is *Fasciolopsis buski*, an intestinal fluke acquired from eating raw aquatic vegetables. Neither of these parasites causes catastrophic illness, but the diversion of nutrients to the parasites and their other insidious effects make life less satisfactory than it otherwise would be. The family also suffers from other intestinal worms occurring in even greater numbers and causing more illness (these are discussed in relation to another family, below).

One more infection attends the family's lack of safe excreta disposal. Within the pits of the latrines that have been flooded and abandoned, the liquid waste is colonized by mosquito larvae of the *Culex pipiens* group. When the adult mosquitos bite the members of the household, they transmit into the bloodstream the larvae of a parasitic worm (*Wuchereria bancrofti*) that lives in the tissues under the skin of the legs and elsewhere, particularly in the lymph nodes, where it blocks the lymphatic flow. Tissues near the blockage consequently become swollen from the accumulation of lymph, and some affected people develop massive elephantiasis. The father of the family is troubled by this in his right leg, which is so swollen that he cannot work in the fields as productively as he could before.

A North African family

The next region visited is quite different in general appearance, but behind this exterior are certain similarities in the disease pattern. The village entered is a cluster of mud brick houses located in the subtropics. It is quite cold in the winter though summer temperatures are at least as high as in the Asian village just visited. The houses cluster on a mound rising from surrounding irrigated areas. The irrigation is from water brought from afar by great rivers, not from heavy rainfall, and the ground is baked hard where it has not recently been irrigated. Within the village the streets are narrow and unpaved, and large quantities of debris lie around.

The family selected consists of the parents, three children, and some elderly relatives. This family has also suffered the death of children from diarrheal disease. (Indeed, it would be difficult to find a tropical or subtropical area in which this is not a problem.)

As in Asia, schistosomiasis and elephantiasis are present. These are of somewhat different varieties, but create disability in similar ways. Although intestinal schistosomiasis occurs here, two of the younger children have a urinary form of the disease and pass blood in their urine every day. This looks more serious than it is (in fact, the blood loss is small); however, the children do suffer the pain and inconvenience of having to get up frequently to urinate at night. Not too long ago their uncle had to go to the hospital in the nearby city, where he was told that he had inoperable cancer of the bladder. He died a very painful death, and the surgeon told the family his death may have been a late consequence of the same infection causing blood in the urine of the children, but that only a few unfortunate people developed cancer from the infection.

The helminths associated with fish and aquatic plants that plagued the previous family are absent from this environment, but microscopic examination of the feces of the family show hookworm (*Ancylostoma*), roundworm (*Ascaris*) and whipworm (*Trichuris*) eggs in large numbers. The hookworm eggs are especially numerous—the infection has been picked up by walking barefoot on land that has been used for defecation and that has been kept moist enough by the nearby drains and canals for the worm larvae to develop in the soil. The mother has a particularly heavy infection. The worms inhabit the small intestine where they attach themselves to the intestinal wall; they are messy feeders, and a large amount of the blood they suck for their growth and production of their eggs passes straight through their bodies and is lost into the intestinal lumen. As a result the blood losses from this infection are high—indeed, the mother's loss is twice as heavy as that from menstruation and, because her diet is not overly rich in iron, she has become anemic and unable to work as hard as a fit person. The same is true of one of the children: his abdomen is swollen; he cannot run fast enough to keep up with the other children, and his condition gives considerable cause for anxiety. Some other infection in addition to the hookworm might well claim his life.

All the family have roundworms. These parasites are quite large (over 100 millimeters long), and every now and then one of the younger children passes one in the stool. This elicits little more than comment, since there is no obvious illness except pain in the abdomen, a complaint difficult to ascribe to a specific cause. What is certain is that the worms are absorbing a good percentage of the nutrients the children need, and there is also the risk that the worms will get stuck in the narrowest part of the intestine and block it, thus necessitating a faraway surgeon's attention. The family are well aware of the problem, and have often visited the dispensary to get medicine. But in the absence of instruction and better methods of disposing of their excreta, the infection comes back every few months. The adults seem to have become somewhat immune to reinfection, and the children carry the brunt of the recurrence.

Most of those, especially the children, who have roundworms also have whipworm infections. These little worms, found mostly on the wall of the colon and rectal passage, have an uncertain effect on most of the family, generally adding to the burden of other parasites. Some while ago a neighbor's child picked up a very heavy infection with the whipworm. The rectal passage gradually prolapsed (that is, got partly pushed out of the anal orifice), which was both painful and unsightly, while an intractable diarrhea that had begun some months earlier persisted and made the child very anemic. A concurrent amebic infection led to some confusion over what was causing which symptoms, but the prolapse was certainly not a regular feature of amebiasis and the diarrhea could have been due to either cause.

What arrangements are made for excreta disposal here? Bore-hole latrines were made for each family's use but they filled up rather quickly and were then so unpleasant that no one wanted to use them. In any case, the latrines were in or near the houses and, because the families spend much of the day in the fields working on their rice and other crops most felt that it would be an unreasonable waste of their time to come all the way back to the house to defecate. It is also more convenient to relieve themselves in the field because their religion insists that they wash the anus after defecation, and there is no water readily available for this purpose within the compound. Because of the varying sites for defecation, roundworm and whipworm eggs are spread widely throughout the environment. The eggs are extremely resistant, even in the harsh climate of this part of the world, and find their way onto vegetables that are eaten raw. Eggs also occur in the mud and sand of the compound, where they readily contaminate the hands of crawling babies.

Another intestinal worm somewhat important in this milieu is the beef tapeworm (*Taenia saginata*), which is acquired from an infected cow by eating its beef undercooked (this readily occurs when a large piece of meat is roasted). The adult tapeworm matures in the intestines, adding segments to its length and competing for the family members' limited nutrients; its eggs, often contained in its swollen segments, are shed in large numbers when a tapeworm segment wriggles out of the anus. These worm segments are frequently ingested by browsing cattle; the worm undergoes further development within the muscles of the cow; the beef is inadequately cooked and eaten, and the cycle of infection is resumed. The family's religion prohibits the eating of pork and so they are spared its tapeworm (*Taenia solium*), whose larvae can develop in human muscles—an added and sometimes fatal hazard.

Except in the case of hookworm infection with its dramatic blood loss, all these helminth infections are so long lasting and ennervating that it is difficult to assess their specific damage; they are all infections that are often underrated because of their widespread occurrence and insidious, drawn-out course. The family also suffers from several acute infections, not only diarrheas but also typhoid and hepatitis. The incidence of typhoid in the village is particularly high because of inadequate excreta disposal. In addition, the presence of schistosomiasis in the inhabitants modifies typhoid and lengthens its course, and up to one in every twenty-five people may become a typhoid carrier in some of these villages, a rate which is an order of magnitude higher than seen elsewhere. Consequently, typhoid is extremely common, no less severe than elsewhere, and an appreciable cause of mortality. Hepatitis also occurs frequently: in the younger children it rarely produces serious symptoms, but in adults the patient may be bedridden for weeks or months, and sudden death is not unknown.

One feature that clearly emerges from the account of this family in North Africa is the extent to which it shares in the excreta-related health problems of the family in Southeast Asia. Indeed, as in few other disease patterns, there is a sameness to most of the serious, frequently transmitted, excreted infections that cannot be avoided: certain infections are peculiar to particular localities, but the pattern of diarrheal disease, enteric fever, numerous viral infections, and intestinal worms is repeated worldwide. Of the major excreted infections, only cholera and schistosomiasis have variable and patchy distributions.

Table 3-1. *Maximum prevalence of excreted pathogens (from table 2-2) by age in indigenous populations of endemic areas*

Pathogen	*Age group of highest prevalence of infection (years)*			
	Babies (0–2)	*Children (3–12)*	*Teenagers (13–19)*	*Adults (20+)*
CATEGORY I				
Balantidium coli			*	*
Entamoeba histolytica		*	*	*
Enterobius vermicularis	*	*		
Enteroviruses[a]	*	*		
Giardia lamblia		*		
Hepatitis A virus	*	*	*	
Hymenolepis nana	*	*		
Rotavirus	*			
CATEGORY II				
Campylobacter fetus ssp. *jejuni*	*	*		
Pathogenic *Escherichia coli*[b]	*	*		
Salmonella				
S. typhi		*	*	*
Other salmonellae	*	*	*	*
Shigella spp.	*	*		
Vibrio cholerae		*		
Yersinia enterocolitica		*	*	*
CATEGORY III				
Ascaris lumbricoides		*	*	
Hookworms[c]		*	*	*
Strongyloides stercoralis			*	*
Trichuris trichiura		*	*	
CATEGORY IV				
Taenia saginata and *T. solium*			*	*
CATEGORY V				
Clonorchis sinensis				*
Diphyllobothrium latum				*
Fasciola hepatica		*	*	*
Fasciolopsis buski		*	*	
Gastrodiscoides hominis		*	*	
Heterophyes heterophyes				*
Metagonimus yokagawai				*
Paragonimus westermani				*
Schistosoma spp.		*	*	*

a. Includes polio-, echo-, and coxsackieviruses.
b. Includes enterotoxigenic, enteroinvasive, and enteropathogenic *E. coli*.
c. *Ancylostoma duodenale* and *Necator americanus*.

Children and Excreta Disposal

Many of the excreted infections examined in this book have a markedly nonuniform distribution among different age groups. Although all the infections are found in people of all ages, many are concentrated in particular age groups. The age groups most afflicted by the main excreted infections in areas where these infections are endemic are shown in table 3-1. The data of the table clearly show that many of these illnesses are primarily childhood infections, or that the infections afflict children as well as adults. This fact has the greatest relevance for disease control through improvements in excreta disposal.

In all societies children below the age of about 3 will defecate whenever and wherever they feel the need. A proportion of these children will be excreting substantial quantities of pathogens. In some societies these children's feces are regarded as relatively inoffensive, and the children are allowed to defecate anywhere in or near the house. In this case it is highly likely that these feces will play a significant role in transmitting infection to other children and adults. This applies not only to those infections without a latency period but also to infections such as ascariasis, in which the defecation habits of children may determine the degree of soil pollution in the yard and around the house and thus the prevalence and intensity of infection in the household. In other societies strenuous efforts are made to control and manage the stools of young children, either by making them wear diapers (nappies) or by cleaning up their stools whenever they are found. Either of these reactions should have an important controlling influence on the intrafamilial transmission of excreted infections.

Between these two extremes is a range of intermediate behavioral patterns by which adults react to the stools of young children. In most poor communities, the pattern is closer to the first reaction than to the second. The relevant response of government and other responsible agencies where these attitudes prevail should be health education programs to encourage in mothers the belief that the stools of young children are dangerous and should be hygienically disposed of. Although the problem is primarily in attitudes and behavior, the provision of some form of toilet for the disposal of a child's stool and, perhaps more important, a convenient water supply will greatly assist child hygiene.

Children over 3 years in age, in contrast, are capable of using a toilet if one of suitable design is available. Children of 3 to 12 years frequently do not use available toilets because they find their use inconvenient and it is not encouraged by adults; they are afraid of falling down the toilet's hole or of being attacked by the pigs that may live next to the latrine; they cannot use a toilet not designed to their scale; or they are prevented from doing so by adults who want to avoid cleaning up the toilet area after them.

As with very young children, it is of vital importance that the stools of children over age 3 be hygienically disposed of because some will be rich in pathogens. The solution lies in providing both toilets that children are happy to use and health education for mothers, so that they will compel their children to use them. Health education for school-aged children could also be effective here, and it is essential that all schools have well-maintained latrines as positive examples for the children.[1]

Distribution of Sanitation Benefits

The transmission cycles typically followed by the infections in categories I through V (table 2-2 and figure 2-5) have been compared and discussed and the shorter or tighter cycles that categories I and II may follow over categories III to V have been indicated. The implication is that categories III to V are associated with a wider spread of their infections, a factor important in the selection of appropriate excreta disposal technology and, in particular, in assessing the willingness of an individual family to adopt an innovation. If, on the one hand, a household head believes, or can be persuaded to believe, that the adoption of a new technology will bring appreciable health benefits to his family, regardless of what is taking place in the neighborhood, then he will be more willing to innovate. If, on the other hand, it is clear that his action alone will have a negligible effect on his family's health, he is more likely to sit back and await clear evidence that a viable and effective improvement program is being carried out throughout his neighborhood.

In cases in which most pathogen transmission is intrafamilial—as in category I and, to a lesser extent, category II—it can be expected that improvement in excreta disposal *and cleanliness* in an individual family may lead to health benefits for that family. In fact, as we have already argued, cleanliness is probably more important than excreta disposal facilities *per se* in the reduction of category I (and to a lesser extent category II) infections, and therefore it is changes in hygienic behavior that may bring the greatest benefit to a single family in isolation from widespread changes in the community's sanitation.

There is one infection from categories III to V—ascariasis—which, although potentially having a long transmission cycle, is frequently transmitted within the family and diminishes with improvements in excreta disposal facilities without accompanying changes in personal cleanliness. Work in China and the US in the 1920's and 1930's showed that poor families, who used their latrines and prevented their children from defecating in the yard, had significantly lower

1. *Indeed, the whole subject of health education, so difficult to* discuss incisively, is crucial to the full realisation of the potential health benefits of improved excreta disposal facilities—see Chapter 8.

intensities of *Ascaris* infection than their neighbors (Otto, Cort and Keller 1931; Winfield 1937). Similar reductions on an individual family basis can be expected from the adoption of improvements in excreta disposal today. There are other specific circumstances in which a given infection may readily be reduced by the independent action of a single family. An example is hookworm in rural India, where in many villages much of the infection occurs when barefoot people visit the communal defecation grounds on the edge of the community. A family which installs a pit latrine and no longer visits the defecation ground may substantially reduce its exposure to hookworm infection. These cases demonstrate that, in planning and implementing an excreta disposal program, officials may find it useful to identify infections for which individual household action may be particularly effective. These infections might then be monitored and the family results used as part of a community propaganda exercise (for example: "the Sanchez family has adopted the new latrine and improved their domestic hygiene and they now have less roundworms than their neighbors").

Health Benefits of Sanitation

Although major health problems are clearly associated with inadequate excreta disposal facilities, to relate the two causally—in particular, to say what the health benefits will be from a given proposed improvement of facilities—is difficult. The difficulties and the studies attempting to overcome them are reviewed in this section. Critical comments must not obscure the fact that without improved excreta disposal many of the diseases discussed will never be overcome, yet other complementary measures—and in some cases major social, economic, and political changes—will generally be required for success.

Methodological issues

Studies of the health benefits of sanitation in the field have either compared disease levels in communities with varying sanitary facilities or monitored disease patterns before and after the improvement of sanitary facilities within a community. In both cases the difficulties in attributing benefits to the improved sanitation have arisen because other variables are often associated with the sanitation facilities. People who have better sanitation than their neighbors often also have higher incomes, better water supplies, and different habits of cleanliness. Similarly, if a single community is followed over time, improvements in the sanitary facilities are likely to be only one among several changes to benefit the community's health. To allocate all the health benefits to improved sanitation alone would therefore be unjustified. Conversely, a study that demonstrates no health improvement after appropriate changes in sanitary facilities cannot validly imply that such changes are useless. The facilities may have been unused for lack of health education or may have been improperly sited—it is often a mistake to generalize from a particular local result.

The economist ideally wishes to use data on health benefits to decide priorities in resource allocation, and the total health benefits are needed for such a decision. However, health as such is not measureable (except, possibly, in the form of statistics on the growth of infants), and it is diseases that are studied instead. Because sanitation affects a range of diseases not all measurable in a single study, a few indicator or index diseases are usually chosen to assess benefits. More often still, particular disease agents—such as *Shigella* bacteria or worm eggs—are assessed in the feces. The resulting measures of how infection rates change as sanitation is applied are several removes from health benefits *per se*, and the intermediate causal relationships are by no means linear. The relation between an infection and the development of disease depends on variables such as: the intensity of infection, nutritional status, other infections, age of the host, and health care available locally.

The literature

Some of the relevant literature on the assessment of health benefits is listed in table 2-1. Almost none of the studies described there reaches the standards of epidemiological demonstration that make a study conclusive; melancholy criticism of the limitations of each paper is therefore avoided. Rather, the conclusions reported in the literature should be taken as an indication of trends.

An important component of any evaluation, but one that is much neglected, is time. The attainment of comparability between an area that has experienced sanitary interventions and one that has not requires that surveys be done soon after installation of the sanitary facilities. In the common case, observations are recorded only for up to a year and are begun months after construction. Such information has poor predictive value for the long term. If a special campaign has been mounted in relation to new facilities, the results may be transiently impressive but may fall off over time. Conversely, the community may take some years to adjust to and use the innovations, so that a short-term study fails to demonstrate the real benefits changes bring. Even if these problems are avoided through long-term study or the observation of variations between communities with long-established differences in excreta disposal patterns, the difficulty of confounding variables arises: it is most unlikely that communities will stay comparable in all differences other than excreta disposal and its consequences over many years.

Considering these complexities, it is not surprising that studies on the benefits of excreta disposal assessed by health changes in the field are almost all of an insufficient standard to be convincing. Few indeed can be described as scientifically impeccable and productive of results inspiring confidence. This discussion of methodology might be considered niggling and academic if most of the published studies gave concordant results—but this is not the case, and some studies are frankly contradictory. Again, a detailed critique of each study listed in table 2-1 is not given because these defects in sampling, comparability of samples, and confounding variables recur with such consistency, whereas the actual use of facilities provided is scarcely ever assessed. A further methodological difficulty is that, in studies using recurrent medical treatment, observations are made during periods too short in duration to show long-term outcomes and to detect the large rise in noncompliance with therapy that tends to occur in time.

If all the studies in table 2-1 were summarized, however, they would collectively suggest that it is reasonable to hope for a halving of the incidence of category III, IV and V infections through improved excreta disposal facilities and concomitant supporting programs for facility maintenance and health education. If such programs are combined with safe water supply and appropriate behavioral changes, the risk from some other serious excreta-related diseases can become small, and such illnesses as typhoid and cholera (category II) can cease to be endemic. The impact of improved excreta disposal on category I infections is likely to be small in the absence of major improvements in domestic conditions, which may imply substantial socioeconomic change in the community at large.

Limitations in Assessing Health Benefits

The planner seeks a clear, preferably monetary, statement of the health benefits of alternative sanitation improvements. The data are not adequate to provide one. It is quite feasible to list the present costs of treating sanitation-related diseases, but these estimates are small in relation to the estimates of the work and life lost to these diseases. The latter estimates themselves are subject to great uncertainty, and any figures put on such losses may be largely spurious.

Two examples may be given. Wagner and Lanoix (1969) attempted to estimate the costs of diarrheal disease and found that the largest component was from premature death in children under the age of 2 years. There are several means of placing an economic value to death at this age that give widely differing answers. More recently Latham, Latham and Basta (1977) estimated the cost of *Ascaris* infection to Kenya. The largest single component was the estimated reduction in food absorption and utilization by those infected, given as US$4.4 millions yearly, as compared with a total of US$0.7 million for all other costs such as present treatment, health care, and transport to health care facilities. Yet it is possible to pose reasons for the US$4.4 millions varying by ± 50 percent.

It is also possible, however, to make informed assessments of the comparative benefits of different excreta disposal systems, and this is attempted below. No cost figures on different excreta disposal systems are given here—these may be found in the various other documents issuing from the World Bank's investigations of appropriate sanitation technologies.[2] It will be clear from our discussion of human behavior here and in chapter 8 that the greatest determinants of the efficacy of alternative facilities are, first, whether they are used by everyone all the time, and second, whether they are adequately maintained. Use will be dependent on the locality concerned: for instance, in urban situations, where alternative defecation sites are scarce, it will be easier to ensure widespread use of new facilities. There are also both private and public aspects to maintenance of all but basic on-site systems, and systems vary in their public maintenance needs (some withstand public neglect better than others).

Best inferences in an optimal case

In the evaluation of the health benefits of excreta disposal, an optimal situation would be one in which everyone uses the facilities all the time and the town council responsible for their maintenance is meticulous in its duties. A corresponding worst case would be the total lack of sanitation facilities. In both cases, it is the disposal technologies rather than management systems that are the objects of comparison. The baseline

2. See, for example, Kalbermatten, Julius and Gunnerson (1982) and Feachem, Mara and Iwugo (1980).

situation will vary greatly in the absence of any sanitary provisions. Where population densities are high, as in many parts of rural Asia and in all the world's major cities, the base level of disease caused by excreted pathogens will be quite high. On a crude scale of ill health, this situation would be rated at 0. Where conditions include flush toilets, sewers and an efficient treatment plant—the best case—the resulting health benefits will rate a 10 as long as water supplies are adequate for optimal use of the sanitation system.

Although not adapted to the water use levels needed for the personal cleanliness required to minimize the infections of categories I and II (see table 2-2), pit latrines would, from the viewpoint of health rather than convenience, approximate the same rating as a waterborne sewerage system. Because a pit latrine has no effluent or product, it is in this regard safer than a sewerage system producing large volumes of a polluted effluent that is in general, even in the best treatment plants, not made completely pathogen free. A rating of 9 is given to pit latrines (but this rating does not apply wherever fecal material might soak through latrine walls to gain access ultimately to drinking water or wherever flooding or a high water table regularly recur).

Where composting, double-vault latrines (a rating of 8) are used and are dug out frequently, a residual hazard from long-lived helminth eggs persists and benefits are less. Reuse of the compost will further spread the eggs in the community. The "multrum" composting toilet is, again, safe if operated ideally, but in general its risks tend to be greater (hence a rating of 7) because the latrine's continuous process involves hazards from insufficiently composted pathogens.

An aquaprivy with a retention time longer than a month may yield an effluent with a low pathogen content, but this requires the regular addition of water to the tank at a rate that will not seriously reduce the retention time. Provided that an efficient sludge removal and treatment system is available, the resulting health benefits from the aquaprivy might approximate 9 on the scale. A septic tank with a retention time of only 1–3 days produces an effluent rich in pathogens and therefore is associated with greater risk (a rating of 8 is assigned). With a bucket-latrine system, major reductions in disease are unlikely, even in an ideal world, and a rating of 5 is considered appropriate. A well-managed vault and vacuum-truck cartage system would be a great improvement, but some risk of spillage and contact with fresh feces would still exist (hence a rating of 8).

The preceding ranks the health benefits of mainly on-site systems. If excreta are transported by cartage or water to a treatment plant, oxidation ponds for sewage, and batch thermophilic composting for night soils and sludges, will give a safe product. Alternative processes in treatment plants are inferior.

Best inferences in actuality

In the real world, of course, systems are not maintained impeccably, nor are facilities invariably used. Moreover, some systems clearly require less effort to maintain and use than others. Cartage in some Japanese towns using vacuum trucks is fully comparable to waterborne sewerage (Kalbermatten, Julius and Gunnerson 1982). In some cities in other countries, however, the great majority of trucks are typically out of operation. Health benefits are closely tied to operation and use, and some societies are better than others at operating particular systems. If change is contemplated, much greater effort than hitherto assumed may need to be allocated to the operation and use, rather than the installation, of new facilities.

Operation and maintenance require both user effort and municipal endeavor, and the necessary blend between these differs according to the chosen technology. A ranking of the various disposal technologies by ease of maintenance for the user and the municipality, water requirements, and the ideal (as discussed in the section above) and actual health benefits is given in table 3-2. It should be noted that the ideal benefits vary little among processes when the facilities are well maintained and used; only bucket latrines are intrinsically and substantially inferior. The proposed ranking of actual benefits reflects variables leading to neglect of the particular facilities, but this is a very provisional evaluation, and many other factors must be taken into account in selecting technology for a given site. The informed speculation in table 3-2 is intended to stimulate thought about the health-related aspects of technology choice, and to draw attention to the disparate advantages of the pit latrine and the bucket system.

Literature Cited

Feachem, R. G. A., Mara, D. D. and Iwugo, K. O. (1980). *Alternative Sanitation Technologies for Urban Areas in Africa*. Appropriate Technology for Water Supply and Sanitation, vol. 7. Washington, D.C.: The World Bank, Transportation, Water and Telecommunications Department.

Kalbermatten, J. M., Julius, D. S. and Gunnerson, C. G. (1982). *Appropriate Sanitation Alternatives: A Technical*

Table 3-2. *Ranking of excreta disposal technologies by ease of operation and maintenance, water needs, and health benefits*
(scale of 10)

Technology	Lack of effort required[a] By user	Lack of effort required[a] By municipality	Water needs	Health benefits[b] Ideal	Health benefits[b] Actual
Flush toilet/ sewers/oxidation ponds	10	4	H	10	9
Vault/vacuum truck	8	0	L	8	6
Pit latrine	8	5	L	9	6
Septic tank	6	5	H	8	7
Aquaprivy	5	5	M	9	6
Bucket latrine	3	1	L	5	1
Batch composter (double vault)	1	10	L	8	5
Continuous composter (multrum)	0	10	L	7	3

L Low; M medium; H high.
a. 0 = maximum effort; 10 = minimum effort.
b. 0 = no benefits; 10 = maximum benefits.

and Economic Appraisal. World Bank Studies in Water Supply and Sanitation, **1**. Baltimore, Md.: Johns Hopkins University Press.

Latham, L., Latham, M. and Basta, S. S. (1977). *The Nutritional and Economic Implications of Ascaris Infection in Kenya.* World Bank Staff Working Paper no. 271. Washington, D.C.

Otto, G. F., Cort, W. W. and Keller, A. E. (1931). Environmental studies of families in Tennessee infested with *Ascaris*, *Trichuris* and hookworm. *American Journal of Hygiene*, **14**, 156–193.

Wagner, E. G. and Lanoix, J. N. (1969). *Water Supply for Rural Areas and Small Communities.* Geneva: World Health Organization.

Winfield, G. F. (1937). Studies on the control of faecal-borne diseases in North China. III. Family environmental factors affecting the spread of *Ascaris lumbricoides* in a rural population. *Chinese Medical Journal*, **51**, 643–658.