2

Environmental Classification of Excreta-related Infections

VARIOUS DISEASES are related to excreta, and the engineer, administrator, and community development worker cannot consider each disease separately in selecting improved excreta disposal technologies. Rather, a conceptual framework that links various kinds of excreta-related infections to the design and implementation of particular disposal or reuse technologies is required. Yet a biological classification grouping the excreted viruses, bacteria, protozoa, and helminths may be less helpful to understanding the health aspects of alternative approaches to excreta disposal than a classification of infections based upon transmission routes and life cycles. Such a classification would be an "environmental" one. In fact, the resemblance between a biological and an environmental classification is much closer in the case of the excreta-related infections than in the case of the water-related infections (see Bradley 1977).

The purpose of an environmental classification is to group infections in such a way that the efficacy of different preventive measures is made clear. An environmental classification for the water-related infections has already been proposed (Bradley 1977; Feachem, McGarry and Mara 1977); the object here is to propose an environmental classification for the infections associated with excreta. The devising of such a classification encounters two major limitations. The first is that remarkably little is known precisely about the transmission of several of these infections and the numbers of microbes needed to pass on the infections to susceptible people. The second is that the bulk of the excreted viruses, bacteria, and protozoa differ quantitatively rather than qualitatively in their transmission characteristics, making it easy to end up with a large, relatively uninformative category containing the majority of infections. Understanding these infections depends on some basic facts of transmission—especially latency, persistence of pathogens in the environment, and the infective dose for humans—and these and other key concepts are discussed before the environmental classification is set forth.

Understanding Excreta-Related Infections

Excreta may be related to human disease in two ways (figure 2-1). The agents of many important infections escape in the body's excreta eventually to reach others—the first means of relation—and these are "excreted infections." In some cases the reservoir of infections escape in the body's excreta eventually to Because such infections cannot be controlled through changes in human excreta disposal practices, this study does not examine them. (A number of infections for which both man and other animals serve as a reservoir, however, have been included.)

The second way in which excreta relate to human disease is through the insect breeding that waste disposal often encourages. Insects may be a nuisance in themselves (as are flies, cockroaches, mosquitoes), but they may also mechanically transmit excreted pathogens either on their bodies or in their intestinal tracts (as do cockroaches and flies), and sometimes

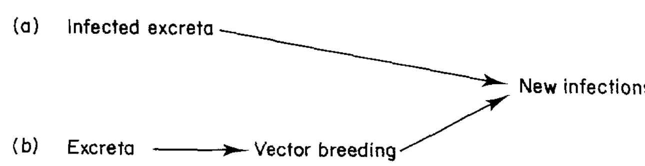

Figure 2-1. *The links between excreta and infection.* In (a), the excreta themselves contain the pathogens which may be transmitted by various routes to a new host. In (b), the excreta (or sewage) permits the breeding of certain flies and mosquitoes that may act as vectors of excreted and other pathogens

they may be vectors for pathogens that circulate in the blood (as are mosquitoes). The capacity of flies or cockroaches to serve as mechanical vehicles for excreted pathogens represents one of the many ways in which excreted disease agents are transmitted from anus to mouth. Careful disposal of human wastes, precautions in food storage and handling, and control measures directed against flies and cockroaches would minimize the threat to health of these pests. The blood-feeding nature of the mosquito, however, poses a more complex problem. The mosquito ingests agents of the diseases it transmits through biting already infected persons and perpetuates the cycle of infection to new hosts by the same means. The pathogens it carries are therefore nonexcreted, and the concepts discussed in this chapter have little relevance; the important factors are those which determine the breeding habits of those particular mosquito vectors that breed in sewage or sullage.[1]

The distinction between the state of being infected and the state of being ill must be kept in mind in considering the transmission of excreted infections. The most important segment of the population involved in transmitting an infection frequently shows few or no signs of disease; conversely, individuals in advanced states of disease may be of little or no importance in transmission. Schistosomiasis is a good example: as much as 80 percent of the total egg output in feces and urine reaching water from a human population may be produced by children 5 to 15 years old, many of whom will show minimal signs of disease. Conversely, middle-aged people in terminal stages of schistosomiasis may produce few or no viable schistosome eggs.

If an excreted infection is to spread, an infective dose of the disease agent has to pass from the excreta of a patient, carrier, or reservoir of the infection to the mouth or some other entryway of a susceptible person. Spread will depend upon the numbers of pathogens excreted, upon how these numbers change during the particular transmission route or life cycle, and upon the dose required to infect a new individual. Infective dose is in turn related to the susceptibility of the new host. Three key factors intervene to govern the probability that, for a given transmission route, the numbers of excreted pathogens (excreted load) from one host will form an infective dose for another: latency, persistence, and multiplication. These concepts will be discussed in turn; their relation is expressed in figure 2-2.

1. See category VI in the next main section of this chapter. The relation of insects to excreta and disease is examined in detail in chapters 36 and 37.

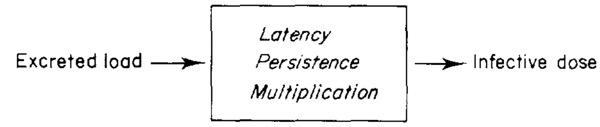

Figure 2-2. *Factors affecting the transmission of an infective dose*

Excreted load

The concentration of pathogens passed by an infected person, or excreted load, varies widely. A person infected by a small number of nematode worms, for instance, may pass only a few eggs per gram of feces, whereas a cholera carrier may excrete 10^6 vibrios per gram, and a patient with an acute attack of cholera may pass 10^{13} vibrios in a day. In areas where large numbers of pathogenic organisms are being passed in the feces, high pathogen concentrations in sewage are common (see table 1-10). Even in a developed, temperate country such as England, where water use is relatively high and salmonellosis relatively rare, raw sewage may contain 10^4 salmonellae per liter. At these concentrations a removal efficiency of 99 percent in sewage works will still leave 10^2 pathogenic organisms per liter of effluent. The health implications of these pathogens will depend upon the effluent disposal method, the pathogens' ability to survive or multiply, and the infective dose required.

Latency

Latency is the interval between the excretion of a pathogen and its becoming infective to a new host. Some organisms—including all excreted viruses, bacteria, and protozoa—have no latent period and are immediately infectious in raw excreta. The requirements for the safe disposal of excreta containing these agents are different from those for helminthic infections which have prolonged latent periods. Latency can affect the choice of disposal systems: infections that have a considerable latent period are largely risk free in carted night soil, whereas the others constitute a major health hazard in fresh night soil. In the environmental classification that follows, therefore, the first two categories, in which no latency is observed, are separated from the remaining categories, in which a definite latent period occurs.

Among the helminthic infections (see table 1-9), only three have eggs or larvae that may be immediately infectious to man after being passed in the feces. These are the pinworm (*Enterobius vermicularis*), a dwarf tapeworm (*Hymenolepis nana*), and occasionally a minute nematode (*Strongyloides stercoralis*). All the other excreted helminths require a distinct latent period, either because their eggs must develop into an infectious stage in the environment outside the body, or because these parasites have one or more intermediate hosts through which they must pass in order to complete their life cycles.

Persistence

Viability of the pathogen in the environment, or persistence, is a measure of how quickly it dies after leaving the human body. This single property is the most indicative of the fecal hazard: a highly persistent pathogen will create a risk throughout most treatment processes and during the reuse of excreta.

A pathogen with short persistence outside the body, however, must rapidly find a new, susceptible host. Transmission, therefore, cannot follow a long route through sewage works and the final effluent disposal site back to man, but will rather involve the family or other close group, within which infection is transferred from one person to another through lax personal cleanliness. More persistent organisms, in contrast, can readily generate new cases of disease much farther afield. As persistence increases, so then must concern for the ultimate means of excreta disposal. Similarly, pathogens that tend to persist in the general environment will require more elaborate processes to inactivate them in a sewage works. Methods of sequestering these pathogens, such as sedimentation into a sludge for special treatment, are often needed.

Measurement of pathogen persistence in a laboratory is easy. Laboratory results, however, need confirmation by field studies which are more difficult. Interpreting field results on persistence requires knowledge of how many pathogens are being shed in a community's excreta (relatively easy to determine) and the infective doses for man (extremely difficult).

Multiplication

Under favorable conditions certain pathogens will multiply in the environment. Originally low numbers can thus produce a potentially infective dose (see the next section). Bacteria may multiply on a favored substrate (for instance, *Salmonella* on food) and trematode worms multiply in their molluscan intermediate hosts. In the former case, light fecal contamination may increase bacterial numbers to the high minimal infective doses required in many excreted bacterial infections. This may determine the usual mode of infection, since multiplication in water is rare and limited compared with the massive increases possible in food. Excreted viruses and protozoa do not multiply outside their animal hosts.

Among the helminths transmitted by excreta, all the trematodes infecting man undergo multiplication in aquatic snails. This aquatic stage in their life cycles introduces a prolonged latent period of a month or more while the trematodes develop in the snail, followed by an output to the environment of up to several thousand larvae for each egg reaching the water. (Category V of the environmental classification below contains infections of this sort.)

Infective dose

In a predictable world the assessment of health risk could simply be calculated from the output of pathogens in the excreta of those infected, the median infective dose (ID_{50}) of particular organisms, and the efficiency of excreta treatment processes in inactivating pathogens. Because of the variable infective dose of most pathogens and the uneven distribution of infection in the environment, the real world is much less calculable than this. Although the minimal infective dose for some diseases may be a single organism, or very few, the doses required in most bacterial infections are much higher. Data on infective doses are very hard to acquire, since they involve administering a known dose of a pathogen to a human volunteer. Information is scanty and concerned with doses required to infect half those exposed (ID_{50}), rather than a small proportion, at a single exposure. The volunteers generally have been well-nourished adults usually from non-endemic areas. Results of this kind must therefore be applied with great caution to malnourished peasant children continually exposed to an infection. It has been found that changes in the manner of administering experimental doses, such as preceding a dose of cholera vibrios with an alkaline substance to reduce temporarily free gastric acid, may lower the ID_{50} of such organisms by a factor of 10^3 (Hornick and others 1971). And, although ID_{50} may be the most reliable gauge of infectivity in human experimental studies, in natural transmission the infective dose for 5 percent or less of the population may be of greater epidemiological significance.

Uncertainty over the size of the minimal infective dose in nature makes it a difficult criterion to use in devising a classification; nevertheless, it is too important to be left out. The difficulties are greatest with the major excreted bacterial infections and with protozoa. For excreted viruses there is evidence of low ID_{50}s in the laboratory, and in human populations (World Health Organization 1979). In helminthic infections a single egg or larva can infect if ingested, even though a high proportion of worms can fail to mature (especially in locations where immunity is present).

Host response

Host response is important in determining the effect once an individual has received a given dose of an infectious agent. Acquired immunity, and the relation of age to pathology, are particularly important in predicting the effects of sanitation. At one extreme would be infection with a short-lived parasite to which little immunity develops and for which the relation between infection and disease is not age dependent. A close, almost linear relationship between exposure and disease might be expected in this case, with appropriate improvements in sanitation yielding health benefits proportional to effect. *Ascaris* closely approximates this model.

At the other extreme would be infection with viruses or bacteria to which long-lasting immunity develops and for which the chance of overt, symptomatic disease in those infected rises with increasing age. An example of this case is infection with poliovirus (see table 1-5). Under poor sanitary conditions all persons are infected at a young age, older children and adults are immune, and disease is limited to a few of the youngest children, who may suffer chronic paralysis. If sanitation is improved, infection is deferred to later in life, when its pathological consequences are more serious. Thus, although poliovirus transmission may be reduced by improving sanitation, improvements will not necessarily curtail the disease, a result achieved in practice by immunization. This pattern may also apply to other excreted infections such as infectious hepatitis, and it has been proposed for typhoid. There are several other excreted infections, however, in which human immunity is of importance in regulating the amount of disease. Immunity tends to diminish the health significance of moderate sanitary improvements, and may in part explain the disappointing effects of some sanitary programs (table 2-1).[2]

In other words, the balance between exposure to infection and host response to it will determine the pattern of the excreta-related disease. If transmission, creating exposure to a particular infection, is limited, then most people will not have encountered the infection and will be susceptible. If a sudden increase in transmission of the disease occurs, it will affect all age groups in the form of an epidemic. Under these circumstances improvements in sanitation that strike at pathogen transmission will have a considerable

2. See also chapter 3 for a detailed discussion of the health benefits from improvements in sanitation.

Table 2-1. *Summary of selected literature on the effect on health of improved excreta disposal*

Country and type of study	*Finding*	*Source*
Brazil		
In a village of 1,041 inhabitants, a socioeconomic and schistosomiasis survey in 1961 was followed by introduction of schistosome control measures, including latrines, water supplies, laundry facilities, showers and health education. Fecal surveys were carried out in 1961, 1966, 1967 and 1968. Other villages without these interventions were surveyed in 1963 and 1969.	From 1961 to 1968, *Schistosoma mansoni* prevalence rates fell from 7 to 0 percent among 0–4 year olds, from 27 to 4 percent among 5–9 year olds and from 56 to 9 percent among 10–14 year olds. The prevalence of *S. mansoni* infection in domestic rodents and snails also fell considerably. The cost of the control measures was US$0.98 per month per protected person over 7 years.	Barbosa, Pinto and Souza (1971)
Colombia		
15 municipal primary schools in a poor suburb of Cali were visited and 8,444 schoolchildren were interviewed. The school's toilet facilities were inspected and the children were asked if they had had diarrhea, vomiting, colds or headlice over the past week. The observations of toilet facilities were used to compute a "hygienic score" for each school.	Diarrhea and vomiting were more common among children in schools with lower hygienic scores. The individual factors most associated with diarrhea prevalence were feces in the toilet bowl, and an absence of toilet paper, towels, soap or taps for hand washing. Hygienic scores were not related to colds or headlice, and classroom crowding was weakly related to vomiting, colds and headlice.	Koopman (1978)

Table 2-1 *(continued)*

Country and type of study	*Finding*	*Source*
Costa Rica		
Diarrheal morbidity, intestinal bacteria, parasites, quality of water, meat and milk and the fly population were surveyed among 1,202 houses. Three types of excreta disposal facility were distinguished: none (12 percent of houses), pit latrine (76 percent of houses) and flush toilets with septic tanks (12 per cent of houses).	*Ascaris* prevalence decreased as the type of excreta disposal improved. *Trichuris* prevalence was the same among individuals with or without a latrine but was lower among individuals having a septic tank. *Shigella* organisms were not recovered where a septic tank was present. Diarrhea morbidity was *least* amongst those living in houses with no latrine. Excreta disposal facility was not associated with protozoal prevalence.	Moore, de la Cruz and Vargas-Mendez (1965)
An outbreak of 167 cases of infectious hepatitis was investigated between December 1963, and July 1964. The outbreak occurred during a severe drought. Person-to-person contact was considered the likely mode of spread.	Infectious hepatitis cases occurred in 1.6 percent of houses with a flush toilet, 2.7 percent of houses with an outdoor latrine and 2.6 percent of houses with no facility.	Villarejos and others (1966)
Egypt		
Surveys were made in 1952 of helminthic and protozoal infections in two neighboring villages: A and B. Village A had been surveyed in 1950. Village A had improved water supply, a borehole latrine in 90 percent of houses, a refuse collection service and visiting nurses. Village B was untouched.	Protozoal prevalence rates and the mean number of protozoal infections per person were not reduced in Village A. *Ascaris* and hookworm prevalence rates and intensities were reduced.	Chandler (1953 and 1954)
Prisoners used bucket latrines and treated Nile water. Nearby villagers had no latrines and used untreated Nile water. Parasite infections of the villagers were compared with those of the prisoners after various periods of incarceration.	Schistosomiasis and hookworm prevalences in the local population were approximately 75 percent and 70–88 percent respectively. Among prisoners, the rates fell from 30 percent and 68 percent respectively to less than 20 percent in both cases after 5 years of incarceration and to about 10 percent after 12 years. Reinfection with *Ascaris* occurred regularly owing to contamination of sewage-irrigated vegetables.	Khalil (1931)
Various combinations of latrines and drug therapy were investigated in villages for 6 years from 1928.	Latrines had no impact on *Ascaris*, hookworm or schistosome infections.	Scott and Barlow (1938)
Various combinations of water supply, latrines, refuse disposal, fly control and therapy were investigated in 5 villages during 1948–51.	The installation of water supply and latrines did not alter the infant mortality or crude death rates and did not change the fly status in any of the villages.	Weir and others (1952)
Guatemala		
Acute diarrheal rates among families having a latrine were compared with rates amongst those with no latrine.	In those families having a latrine, diarrheal rates were somewhat lower for those over 2 years old, but not for those under 2.	Gordon and others (1964)
Two lowland villages were studied during 1973–76. In-house water supply and sanitary education were implemented in one village; the other village provided a control.	The results of this study have not yet (mid-1981) been fully published. Preliminary reports indicate that malabsorption was somewhat lower in the intervention than the control village, that there were no differences in overall diarrhea incidence but that there was less diarrhea among 2–7 year olds in the intervention than the control village.	Schneider, Shiffman and Faigenblum (1978); Shiffman and others (1979)

Table 2-1 *(continued)*

Country and type of study	*Finding*	*Source*
India		
The impact of a bored-hole pit latrine and health education program on the incidence of diarrhea in children in the village of Bharwara, near Lucknow, was investigated.	The authors state that the invervention was related to "a declining trend in diarrhoeal morbidity", but the data presented do not support this.	Kumar, Sehgal and Singh (1970)
A single stool examination on 13,267 hospital patients and their contacts was carried out at Karnal, Haryana State. A sanitary inspector was sent to the homes of the patients to collect information on hygiene and domestic facilities.	The prevalence of *Entamoeba histolytica* excretion among those living in homes with no latrines (38.3 percent) was a little higher than for those using latrines (31.6 percent) ($p<.01$). The authors point out that this difference cannot necessarily be attributed to the latrines.	Mathur and Kaur (1972)
Iran		
Impact of mass treatment, sanitation and sanitation plus mass treatment on soil-transmitted helminths was studied in 15 villages in southwest Iran. Sanitation was one pit latrine per family and a communal water supply.	Mass treatment was highly effective in reducing both the prevalence and intensity of *Ancylostoma* and *Ascaris*. Sanitation, added to mass treatment, contributed nothing. Sanitation alone had an impact upon the intensity of both hookworm and roundworm and had a little impact on the prevalence of roundworm only.	Arfaa and others (1977)
Ascariasis was studied in a village of 850 people in southwest Iran before and after the construction of a water supply, a public bath-house, a laundry and 114 pit latrines (nearly one for every household).	The prevalence of infection fell from 67 percent to 57 percent over the study period (February 1963 to December 1965). Mean egg output fell from around 11 per milligram of feces to 4. The pit latrines cost US$0.5 per capita and were the major cause of the reduced ascariasis.	Sahba and Arfaa (1967)
Japan		
A program of heat treating (with firewood) of night soil (up to 60°C) prior to agricultural application was implemented in a village in Shiga Prefecture. A control village was left untouched.	The prevalence of hookworm and *Ascaris* declined "strikingly" in the intervention village and there was a marked decrease in the count of *Ascaris* eggs found in the soil. These changes were not observed in the control village.	Katayama (1955)
Heat treating of night soil (with surplus night electricity) was implemented in a village near Osaka city.	Night soil treatment alone had only a slight effect on the prevalence of parasite infections. When mass chemotherapy was carried out, prevalences fell markedly (hookworm from 52 percent to 11 percent, *Ascaris* from 33 percent to 12 percent) and remained at this low level throughout the 5 month observation period.	Kawagoe and others (1958)
Night soil treatment with thiabendazole was implemented in a village of 5,000 people near Tokyo. Three areas were distinguished: Area A, night soil treatment + chemotherapy; Area B, night soil treatment only; Area C, chemotherapy only. Parasite prevalence was surveyed between July 1964 and March 1966.	The prevalence of ascariasis fell by 50 percent in Area A, by 30 percent in Area B and hardly at all in Area C. The rate of new infections with *Trichuris* was one-third, and that of hookworm was one-half, in Area A compared with Area C.	Kutsumi (1969)
Mauritius		
Diarrheal rates in households with differing sanitation facilities were studied in 1960.	Compared with families with an indoor toilet, families with an outdoor toilet had 4 times the diarrhea incidence and families with no toilet had 10 times the diarrhea incidence.	van Zijl (1966)
Panama		
A series of egg counts were made in two villages, one partially sanitated and the other entirely without latrines, before and after mass chemotherapy.	Reinfection after mass treatment was rapid, but reinfection with hookworm was delayed in those groups with more and better maintained latrines.	Cort, Schapiro and Stoll (1929)

Table 2-1 *(continued)*

Country and type of study	*Finding*	*Source*
Panama (cont.)		
Children presenting at a clinic in Panama City were examined for excretion of enteropathogenic *Escherichia coli*, *Shigella* and *Salmonella*. These data were related to information about type of housing and sanitary facilities.	The three pathogens were absent from children coming from the best housing type, whereas for other housing types, about 8 percent of children had one or more of the pathogens in their feces.	Kourany and Vásquez (1969)
Surveys were conducted over 7 years into environmental conditions and helminthiases.	In villages without latrines, the prevalence and intensity of hookworm rose to, or above, original levels within 3 or 4 years after a mass drug campaign. In villages with latrines, prevalence and intensity also rose again following drug treatment but a degree of protection against reinfection was observed among women.	Sweet and others (1929)
Philippines		
A region with endemic cholera was divided into 4 areas: Area A, control area having poor water and sanitation facilities; Area B, improved water supply; Area C, pour-flush pit latrines; Area D, improved water supply and communal latrines.	The apparent reductions in cholera incidence were 73 percent in Area B, 68 percent in Area C and 76 percent in Area D.	Azurin and Alvero (1974)
Singapore		
159 families living in modern flats and 169 families living in squatter housing were studied. The people in the flats had previously lived in the squatter housing but had been rehoused following a fire in 1961. Average family income of flat dwellers was S$165 per month whereas for squatters it was S$130 per month. Stool samples were collected from all children under 13 years old in the selected households.	*Ascaris*, hookworm and *Trichuris* prevalence rates were 9, 1 and 28 percent, respectively, among flat dwellers and 63, 2 and 58 percent among squatters. The high *Trichuris* prevalence among flat dwellers was attributed to the longevity of this worm.	Kleevens (1966)
St. Lucia		
A longitudinal study of 229 children in three valleys. Weights and heights were recorded monthly; stools were examined for worm eggs every 6 months, and parents kept diarrhea diaries for their children. The children were 0–6 months old at the start of the study and were followed for 2 years.	Children in the valley with improved water and the valley with improved water and latrines had less ascariasis, trichuriasis and diarrhea, and grew better, than children in the valley with no improvements.	Henry (1981)
Sudan		
Diarrhea incidence in households with differing sanitary facilities were studied in 1961.	In one particular month, families having a communal unsanitary privy experienced a higher diarrheal morbidity rate than similar families having no toilet.	van Zijl (1966)
Union of Soviet Socialist Republics		
A village of 1,600 people was studied before and after the abolition of untreated night soil as a fertilizer and a campaign of "improving general hygiene."	Before the intervention, the prevalence of *Ascaris* eggs was 100 percent in soil samples and 71 percent in fruit samples. 41 percent of soil eggs and 19 percent of fruit eggs were viable. After the intervention, 35 percent of soil samples and 25 percent of fruit samples contained eggs. No eggs were viable.	Rosenberg (1960)

Table 2-1 *(continued)*

Country and type of study	*Finding*	*Source*
United States		
400 patients at a veterans' hospital in Georgia had stool examinations for intestinal protozoa and helminths, and completed questionnaires on their military service and living conditions.	The overall prevalence of infection with *Entamoeba histolytica* was 9.3 percent. Among those not infected, 22 percent had outside toilets, whereas among those infected, 55 percent had outside toilets ($p<.01$). Income was not significantly associated with *Ent. histolytica* infection.	Brooke, Donaldson and Brown (1954)
A survey of 357 people in 4 areas near Little Rock, Arkansas, was carried out in 1961. Stools were examined for intestinal protozoa.	The overall prevalence of infection with one or more protozoon (APR) was 33 percent. Among all individuals served with piped indoor water supply the APR was 31 percent, whereas among those using well water it was 35 percent (no significant difference). However, among 0–4 year old piped water users the APR was 13 percent, whereas among 0–4 year old well-water users it was 37 percent ($p<.05$). Many of the houses with piped water also had sewerage, whereas well-water houses had septic tanks or outside pit latrines.	Brooke and others (1963)
2,657 people living in a rural area of West Tennessee were surveyed for intestinal parasites. 90 percent were black. Details of family size, cleanliness, housing, water supply and excreta disposal were also collected.	*Entamoeba histolytica* and *Ascaris* prevalence rates were 19 and 8 percent, respectively, among those with clean latrines, 36 and 11 percent among those with dirty latrines, and 29 and 15 percent among those with no latrines. Parasite prevalence was also found to be associated with family size, fecal contamination of the premises, cleanliness of house and person but not with water pollution.	Eyles, Jones and Smith (1953)
A survey of shigellosis among children under 10 years old in farm labor camps in California was conducted.	The prevalence rates of *Shigella* excretion were 1.6 percent in cabins with inside water, shower and toilet, 3.0 percent in cabins with inside water but shared shower and toilet facilities, and 5.8 percent in cabins with all services shared.	Hollister and others (1955)
White females (age 18–76 years) at a mental institution in California were studied during 1954–57. They were originally housed in an old building in which standards of sanitation were poor. They were then rehoused in a new, modern hospital building with excellent sanitary facilities. Stool examinations were made on 110 patients prior to rehousing and on 8 subsequent occasions.	The percentage of people infected with *Ent. histolytica* and *Giardia lamblia* rose steadily during the survey, indicating that transmission was continuing throughout the period. However, although the percentage of people infected with hookworm (73 percent) and *Trichuris* (83 percent) remained constant, as would be expected in the absence of mass chemotherapy, no new cases of hookworm and only 3 new cases of *Trichuris* were reported while the patients were in the new building. Thus, the move to the new building interrupted the transmission of the helminths but not the protozoa.	Jeffery (1960)
In 1952 a program of borehole latrines was implemented in Boston, Georgia. The prevalence of *Shigella* excretion, in Boston and control towns, was surveyed in children under 10 years old.	The latrine program was associated with a reduction in the detection of *Shigella* from rectal swabs from 4.7 percent to 2.8 percent. Rates in control towns did not fall over this period.	McCabe and Haines (1957)

Table 2-1 (*continued*)

Country and type of study	*Finding*	*Source*
United States (cont.)		
Excretion of *Entamoeba histolytica* among 1,115 urban school children in North Carolina was studied. These data were related to excreta disposal, water supply and garbage disposal facilities in the homes of the children.	*Ent. histolytica* prevalence rates were 6 percent for those with an inside flush toilet, 12 percent for those with a shared flush toilet and 58 percent for those with a pit latrine. Infection with *Ent. histolytica* was also associated with type of water supply and garbage disposal facilities.	Mackie and others (1956)
Hookworm and *Ascaris* surveys were conducted in Virginia.	The introduction of pit privies in the mountainous areas of Virginia was effective in reducing the hookworm prevalence, but not *Ascaris*.	Otto and Spindler (1930)
Environmental studies were made of 329 families in the mountain region of Tennessee and 202 families living in the central basin, western plains and lowlands of the state.	*Ascaris* and *Trichuris* infections were confined largely to the mountain areas. Yard pollution, and with it heavy *Ascaris* infection, were present regardless of the presence or absence of latrines.	Otto, Cort and Keller (1931)
Studies were conducted in 11 mining camps in eastern Kentucky from 1954 to 1957. Reported diarrheal disease rates, *Shigella* isolations from rectal swabs of pre-school children and parasite prevalence were investigated.	*Shigella* and *Ascaris* prevalence rates were 1.1 and 7 percent, respectively, among those with water and flush toilet inside, 2.4 and 25 percent among those with water inside and latrine outside, and 5.9 and 42 percent among those with water and latrine outside.	Schliessmann and others (1958)
Shigella infection data from 28,000 rectal swabs were analysed according to the type of housing. Housing was divided into 4 categories (poor, fair, good, very good) according to water supply, excreta disposal, fly population and esthetic and structural quality.	The rates of new *Shigella* infections occurring during the study period were: 6.2 percent among those in "poor" houses, 2.2 percent among those in "fair" houses, 0.6 percent among those in "good" houses and 0.3 percent among those in "very good" houses.	Stewart and others (1955)

Note: The limitations of the literature on health benefits from sanitation and the difficulties in assessing these benefits are discussed in chapter 3.

effect in reducing an epidemic's likelihood and its magnitude if one occurs.

By contrast, if transmission is vigorous, most people will be repeatedly exposed to an infection, having first acquired it in childhood. Subsequent exposures may be without effect if immunity is developed after the first attack, or immunity may develop cumulatively from a series of attacks. The infection will nevertheless always be present, and can be described as endemic. Under these conditions much of the transmission is ineffective because of human acquired immunity, and reduced transmission through improved sanitation will only delay the occurrence of infection somewhat, so that older children exhibit symptoms. Extensive sanitary improvements will either render the infection rare or, if the disease was originally highly transmitted, make it an adult disease. Diseases exemplifying this state of affairs are typhoid, which can be completely prevented in a community by adequate management of excreta and of water supplies, and poliomyelitis, which can be prevented only by immunization.

The consequences of a disease's juvenile prevalence—not only that children chiefly suffer, but also that children are the main sources of infection—presents a further challenge to sanitation. The acute need for better community excreta disposal must focus on young children, the group perhaps least inclined to use any facilities that are made available.

Nonhuman hosts

Some excreted infections (for example, shigellosis) are confined strictly to humans, and the control of human excreta alone is required for their prevention. Many others (for example, salmonellosis) involve wild or domestic vertebrate animals as well as man. Such an infection is called a zoonosis.

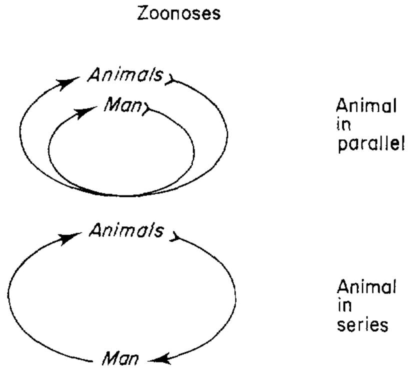

Figure 2-3. *Involvement of other vertebrates in transmission of human excreted infections.* Examples of zoonoses in parallel are salmonellosis and balantidiasis; examples of zoonoses in series are beef and pork tapeworm infections

There are two groups of zoonoses, and each has quite different implications for sanitation (figure 2-3). In the first group, animals act as hosts alternative to man: even if human excreta is under completely safe control, the excreta of other animals can continue to transmit the infection. In effect, the animal involved is "in parallel" with man, and it is necessary to control both human and animal excreta. In the second group, the animal is an essential step in the transmission of the disease from one human to another (figure 2-3, "in series"). In this case, control of either human excreta alone or the animal infection alone will suffice to end transmission. In the environmental classification below, this second group which contains the human tapeworms of the genus *Taenia*, is therefore separated from the other categories.

Some excreted helminthic infections have invertebrate intermediate hosts (see table 1-9); they will be controlled if excreta are prevented from reaching the intermediate hosts, or the intermediate hosts are controlled, or if people do not eat the intermediate host uncooked or do not have contact with the water in which the intermediate host lives (depending on the particular organism's life cycle).

Categories of Excreta-related Infections

There are several ways in which the excreted infections can be grouped according to the epidemiological features discussed above, but a classification that considers the effects of excreta disposal and changes in disposal facilities and technologies has been chosen, and is given in table 2-2. Six categories of infection have been distinguished in the table, and the relevant environmental or epidemiological features broadly considered are latency, infective dose, persistence, multiplication, and transmission. Further data on specific excreted pathogens—arranged by category and epidemiological feature—are provided in table 2-3.[3] Control measures appropriate to each environmental category of pathogen are indicated in table 2-2, and data on immunity and pathogen concentrations in excreta, which vary with each organism, are contained in table 2-3.

There is a clear difference between the first five categories of excreted pathogens and the last, which contains excreta-breeding insect vectors of disease, in that the insects themselves are not pathogens and that a variety of sanitation methods and additional specific measures can be directed against these vectors. For these reasons category VI is not included in table 2-3.

The excreted infections are divided on the basis of the presence (categories III to V) or absence (categories I and II) of a latent period (health problems associated with fresh feces or night soil occur primarily in these first two categories). The distinction between categories I and II and categories III to V is fundamental and clear-cut, corresponding closely to the biology of the pathogens (in that all infections in categories III to V are helminthic).

The subdivisions of the infections having latency are also clear, with category III containing the soil-transmitted worms, IV the tapeworms, which depend on the access of cattle and pigs to human feces, and V the trematodes and other worms requiring aquatic intermediate hosts. The subdivision of categories I and II, however, is difficult and somewhat arbitrary because the various concepts discussed above can arrange the infections of these categories in different ways. If categories I and II are divided, for instance, on the basis of ID_{50} with the grave limitations of the available data on infective dose kept in mind, the approximate ranking of pathogens (in order of increasing ID_{50}) shown in table 2-4 emerges. But if the infections are listed in the order of increasing persistence outside their animal host, the approximate ranking shown in table 2-5 is appropriate. Another important factor in predicting the effects of improved excreta disposal facilities is whether or not a significant nonhuman reservoir of infection (see figure 2-3) exists for a

3. Part Two of the book is devoted to detailed analyses of individual pathogens and diseases according to these and additional environmental factors. But it was thought that, for easier reference, Part Two should group the pathogens by kind and not by the categories described in this chapter. Part Two is divided into section I, the excreted viruses; section II, the excreted bacteria; section III, the excreted protozoa; section IV, the excreted helminths; and section V, the excreta-breeding insects and the diseases they transmit.

Table 2-2. *Environmental classification of excreted infections*

Category and epidemiological features[a]	*Infection*	*Environmental transmission focus*	*Major control measure*
I. Non-latent; low infective dose	Amebiasis Balantidiasis Enterobiasis Enteroviral infections[b] Giardiasis Hymenolepiasis Infectious hepatitis Rotavirus infection	Personal Domestic	Domestic water supply Health education Improved housing Provision of toilets
II. Non-latent; medium or high infective dose; moderately persistent; able to multiply	*Campylobacter* infection Cholera Pathogenic *Escherichia coli* infection[c] Salmonellosis Shigellosis Typhoid Yersiniosis	Personal Domestic Water Crop	Domestic water supply Health education Improved housing Provision of toilets Treatment of excreta prior to discharge or reuse
III. Latent and persistent; no intermediate host	Ascariasis Hookworm infection[d] Strongyloidiasis Trichuriasis	Yard Field Crop	Provisions of toilets Treatment of excreta prior to land application
IV. Latent and persistent; cow or pig as intermediate host	Taeniasis	Yard Field Fodder	Provision of toilets Treatment of excreta prior to land application Cooking, meat inspection
V. Latent and persistent; aquatic intermediate host(s)	Clonorchiasis Diphyllobothriasis Fascioliasis Fasciolopsiasis Gastrodiscoidiasis Heterophyiasis Metagonimiasis Opisthorchiasis Paragonimiasis Schistosomiasis	Water	Provision of toilets Treatment of excreta prior to discharge Control of animal reservoirs Control of intermediate hosts Cooking of water plants and fish Reducing water contact
IV. Spread by excreta-related insects	Bancroftian filariasis (transmitted by *Culex pipiens*) All the infections in I-V able to be transmitted mechanically by flies and cockroaches	Various fecally contaminated sites in which insects breed	Identification and elimination of suitable insect breeding sites

a. See table 2-3 for data on additional epidemiological features by pathogen.

b. Includes polio-, echo-, and coxsackievirus infections.

c. Includes enterotoxigenic, enteroinvasive, and enteropathogenic *E. coli* infections.

d. *Ancylostoma duodenale* and *Necator americanus*.

Table 2-3. *Basic epidemiological features of excreted pathogens by environmental category*

Pathogen	*Excreted load*[a]	*Latency*[b]	*Persistence*[c]	*Multiplication outside human host*	*Median infective dose* (ID_{50})	*Significant immunity?*	*Major nonhuman reservoir?*	*Intermediate host*
CATEGORY I								
Enteroviruses[d]	10^7	0	3 months	No	L	Yes	No	None
Hepatitis A virus	10^6(?)	0	?	No	L(?)	Yes	No	None
Rotavirus	10^6(?)	0	?	No	L(?)	Yes	No(?)	None
Balantidium coli	?	0	?	No	L(?)	No(?)	Yes	None
Entamoeba histolytica	10^5	0	25 days	No	L	No(?)	No	None
Giardia lamblia	10^5	0	25 days	No	L	No(?)	Yes	None
Enterobius vermicularis	Not usually found in feces	0	7 days	No	L	No	No	None
Hymenolepis nana	?	0	1 month	No	L	Yes(?)	No(?)	None
CATEGORY II								
Campylobacter fetus ssp. *jejuni*	10^7	0	7 days	Yes[e]	H(?)	?	Yes	None
Pathogenic *Escherichia coli*[f]	10^8	0	3 months	Yes	H	Yes(?)	No(?)	None
Salmonella								
S. typhi	10^8	0	2 months	Yes[e]	H	Yes	No	None
Other salmonellae	10^8	0	3 months	Yes[e]	H	No	Yes	None
Shigella spp.	10^7	0	1 month	Yes[e]	M	No	No	None
Vibrio cholerae	10^7	0	1 month(?)	Yes	H	Yes(?)	No	None
Yersinia enterocolitica	10^5	0	3 months	Yes	H(?)	No	Yes	None
CATEGORY III								
Ascaris lumbricoides	10^4	10 days	1 year	No	L	No	No	None
Hookworms[g]	10^2	7 days	3 months	No	L	No	No	None
Strongyloides stercoralis	10	3 days	3 weeks (free-living stage much longer)	Yes	L	Yes	No	None
Trichuris trichiura	10^3	20 days	9 months	No	L	No	No	None
CATEGORY IV								
Taenia saginata and *T. solium*[h]	10^4	2 months	9 months	No	L	No	No	Cow (*T. saginata*) or pig (*T. solium*)

CATEGORY V								
Clonorchis sinensis[i]	10^2	6 weeks	Life of fish	Yes[j]	L	No	Yes	Snail and fish
Diphyllobothrium latum[i]	10^4	2 months	Life of fish	No	L	No	Yes	Copepod and fish
Fasciola hepatica[h]	?	2 months	4 months	Yes[j]	L	No	Yes	Snail and aquatic plant
Fasciolopsis buski[h]	10^3	2 months	?	Yes[j]	L	No	Yes	Snail and aquatic plant
Gastrodiscoides hominis[h]	?	2 months(?)	?	Yes[j]	L	No	Yes	Snail and aquatic plant
Heterophyes heterophyes[i]	?	6 weeks	Life of fish	Yes[j]	L	No	Yes	Snail and fish
Metagonimus yokogawai[i]	?	6 weeks(?)	Life of fish	Yes[j]	L	No	Yes	Snail and fish
Paragonimus westermani[i]	?	4 months	Life of crab	Yes[j]	L	No	Yes	Snail and crab or crayfish
Schistosoma								
S. haematobium[h]	4 per milliliter of urine	5 weeks	2 days	Yes[j]	L	Yes	No	Snail
S. japonicum[h]	40	7 weeks	2 days	Yes[j]	L	Yes	Yes	Snail
S. mansoni[h]	40	4 weeks	2 days	Yes[j]	L	?	No	Snail
Leptospira spp.[k]	urine(?)	0	7 days	No	L	Yes(?)	Yes	None

L Low ($<10^2$); M medium ($\approx 10^4$); H high ($>10^6$).

? Uncertain.

a. Typical average number of organisms per gram of feces (except for *Schistosoma haematobium* and *Leptospira*, which occur in urine).

b. Typical minimum time from excretion to infectivity.

c. Estimated maximum life of infective stage at 20°–30°C.

d. Includes polio-, echo-, and coxsackieviruses.

e. Multiplication takes place predominantly on food.

f. Includes enterotoxigenic, enteroinvasive, and enteropathogenic *E. coli.*

g. *Ancylostoma duodenale* and *Necator americanus.*

h. Latency is minimum time from excretion by man to potential reinfection of man. Persistence here refers to maximum survival time of final infective stage. Life cycle involves one intermediate host.

i. Latency and persistence as for *Taenia.* Life cycle involves two intermediate hosts.

j. Multiplication takes place in intermediate snail host.

k. For the reasons given in chapter 1, *Leptospira* spp. do not fit any of the categories defined in table 2-2.

Table 2-4. *Category I and II pathogens (from table 2-2) ranked by median infective dose* (ID_{50})

Pathogen	ID_{50}
Balantidium coli (?)	
Entamoeba histolytica	
Enterobius vermicularis	
Enteroviruses[a]	
Giardia lamblia	L
Hepatitis A virus (?)	
Hymenolepis nana	
Rotavirus (?)	
Shigella	M
Campylobacter fetus ssp. *jejuni* (?)	
Pathogenic *Escherichia coli*[b]	
Salmonella	
S. typhi	H
Other salmonellae	
Vibrio cholerae	
Yersinia enterocolitica (?)	

L Low ($<10^2$); M medium ($\approx 10^4$); H ($>10^6$).
? Uncertain.
a. Includes polio-, echo-, and coxsackieviruses.
b. Includes enterotoxigenic, enteroinvasive, and enteropathogenic *E. coli*.

Table 2-5. *Category I and II pathogens (from table 2-2) ranked by persistence outside host*

Pathogen	*Persistence*
Balantidium coli	
Campylobacter fetus spp. *jejuni* (?)	
Entamoeba histolytica	L
Enterobius vermicularis	
Giardia lamblia	
Hymenolepis nana	
Salmonella typhi	
Shigella spp.	M
Vibrio cholerae	
Enteroviruses[a]	
Pathogenic *Escherichia coli*[b]	H
Salmonellae	
Yersinia enterocolitica	

L Low (<1 month); M medium ($\approx$ 1 month); H high (> 1 month).
? Uncertain.
a. Includes polio-, echo-, and coxsackieviruses.
b. Includes enterotoxigenic, enteroinvasive, and enteropathogenic *E. coli*.

Table 2-6. ID_{50} *and persistence of category I and II pathogens (from table 2-2) commonly and rarely transmitted in affluent European communities*

Pathogen	ID_{50}	*Persistence*
Commonly transmitted		
Campylobacter fetus ssp. *jejuni*	H(?)	L(?)
Enterobius vermicularis	L	L
Enteroviruses[a]	L	H
Pathogenic *Escherichia coli*[b]	H	H
Giardia lamblia	L	L
Hepatitis A virus	L(?)	?
Rotavirus	L(?)	?
Salmonellae	H	H
Shigella sonnei	M	M
Yersinia enterocolitica	H(?)	H
Rarely transmitted		
Balantidium coli	L(?)	L
Entamoeba histolytica	L	L
Hymenolepis nana	L	L
Salmonella typhi	H	M
Shigella (other than *sonnei*)	M	M
Vibrio cholerae	H	M

L Low; M medium; H high.
? Uncertain.
a. Includes polio-, echo-, and coxsackieviruses.
b. Includes enterotoxigenic, enteroinvasive, and enteropathogenic *E. coli*.

particular pathogen; four of the pathogens in categories I and II (*Campylobacter*, salmonellae *Balantidium coli* and *Giardia lamblia*) have significant animal reservoirs (table 2-3).

Socioeconomic considerations would divide the infections in categories I and II in yet another way. Infections that are commonly transmitted in affluent communities (in Europe, for instance) that enjoy high standards in sanitary facilities and hygiene might be expected to be reduced insignificantly by the introduction of limited sanitary improvements in poor communities of the developing countries. An approximate division on these grounds is shown in table 2-6. In some cases the reasons for this division are clear (the salmonellae, for instance, continue to be transmitted from animals to man in affluent communities through contaminated foodstuffs), whereas in other cases (such as the continued transmission of *Shigella sonnei* throughout Europe) they are obscure.

The most useful division of categories I and II has nevertheless proved to be one based on ID_{50}, even though knowledge of the ID_{50} for infections affecting malnourished peasant children in the tropics is nonexistent. With ID_{50} as the criterion, categories I and II break in a way that makes theoretical sense and also correlates in some degree with the likely effects of improved excreta disposal facilities.

The transmission characteristics of the first five categories are illustrated in figure 2-4, in which the typical survival, latency, and multiplication features of the groups of infections are shown. These factors, in turn, affect the "length" of particular transmission cycles. Length has spatial as well as temporal implications, in that a long transmission cycle increases the opportunity of an infection's spreading over a wider area, thus changing the pattern of risk. These issues are developed in the next chapter, and are represented here in figure 2-5, in which the relative efficiency of sanitation improvements in controlling the various categories of infection is also indicated. Each category in table 2-2 implies some minimum sanitary requirements for control of the diseases within it and often control measures ancillary to excreta disposal facilities that further contribute to success. These requirements are elaborated in the discussion that follows.

Category I

These are the infections that have a low ID_{50} ($<10^2$) and are infective immediately upon excretion. We argue that these infections may spread easily from person to person whenever personal and domestic hygiene are not ideal (see figure 2-5). It is therefore likely that changes in excreta disposal technology will have little effect on the incidence of these infections if such changes are unaccompained by sweeping changes in personal cleanliness, which, in turn, may require major improvements in water supply and housing, and major efforts in health education.

But what subsequently happens to excreta—how they are transported, treated, and reused—is of less importance for this group than the transmission of infection in the home. Although transmission can and does occur by more complex routes, most transmission in category I is direct, from person to person, and thus the provision of hygienic toilets alone will have negligible impact. A qualification of category I must follow this statement: categories I and II grade into each other and actually form a continuum (see a further explanation in the next section). In particular, the parasitic protozoa have some features of both groups. One extreme of the category I parasites is the pinworm, *Enterobius*, whose sticky eggs are laid on the anal skin by emerging females, so that transmission is by way of scratching fingers rather than by excretion of eggs in the feces. At the other extreme is *Giardia*, associated with well-documented, waterborne outbreaks of diarrhea, and therefore presumably subject to partial control by excreta management.

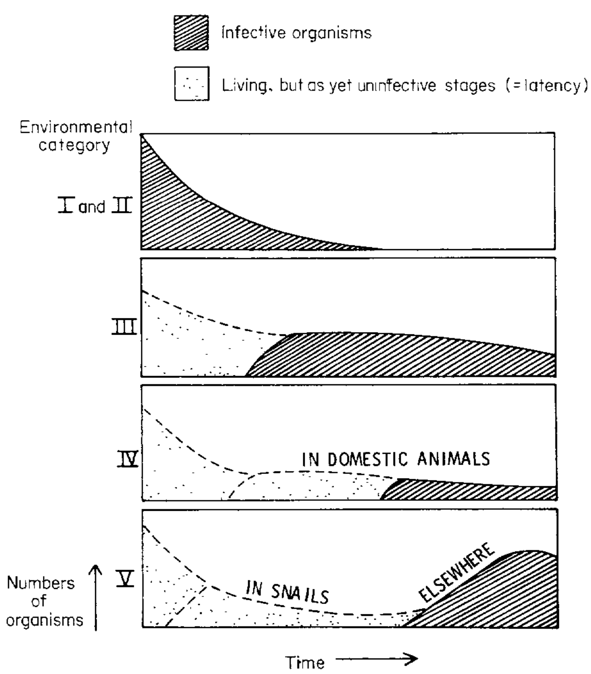

Figure 2-4. *Persistence outside the host of excreted pathogens (categories I–V from table 2-2) over time*

Category II

The infections in this category are all bacterial. They have medium or high ID_{50}s ($\geqslant 10^4$), and so are less likely to be transmitted by person-to-person contact than are category I infections. The bacteria are persistent and can multiply, so that even the small numbers remaining a few weeks after excretion can, if they find a suitable substrate (such as food), multiply to form an infective dose. Direct transmission routes are important, but so too are others with longer environmental cycles, such as the contamination of water sources or crops with fecal material (see figure 2-5). The control measures listed in table 2-2 for category I are important with the added provisions of sound excreta treatment and reuse practice. But, as in category I, changes in excreta disposal and treatment practices alone may have little effect on transmission. Control measures may most affect those infections that—as noted earlier—are not normally transmitted among affluent groups in Europe or elsewhere: cholera, typhoid, and shigellosis (other than *S. sonnei*). Any monitoring or evaluation program would do well to examine these, rather than infections with nontyphoid salmonellae or pathogenic *E. coli*.

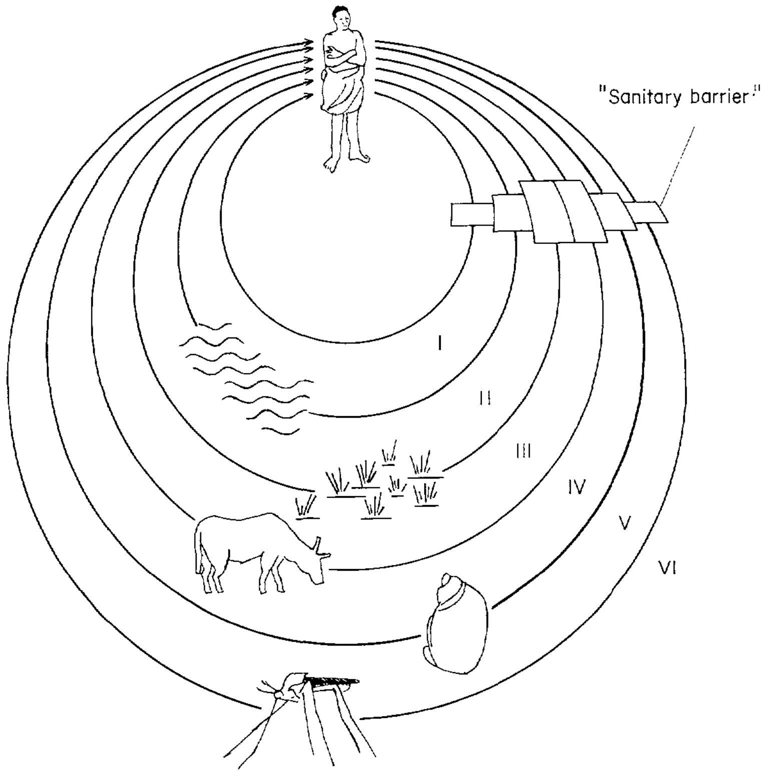

Figure 2-5. *Length and dispersion of transmission cycles of excreted infections (categories I–VI from Table 2-2).* The possible efficacy of improved excreta disposal is indicated by the "sanitary barrier"

The criteria used to differentiate categories I and II have been ID_{50} and length of the environmental cycle, factors with predictive value for the efficacy of sanitation as a control measure. The reason that categories I and II do not form tidy groups is that the persistences of the pathogens involved vary. The extreme category I case—an environmentally fragile organism with a low ID_{50}—will clearly tend to be spread in a familial or similar tight pattern and will depend for its control more on personal cleanliness than on sanitation. (An extreme example, though not excreta-transmitted, can be found in the venereal diseases, which do not survive in the environment and depend on intimate contact for their spread.) However, an environmentally persistent organism with a low ID_{50} will lead to infection difficult to reduce either by sanitation or personal and domestic cleanliness. Many excreted viruses exemplify this pattern and pose such major problems of control that induced immunity may be the best solution (this is certainly the case for poliomyelitis and probably also for infectious hepatitis and rotavirus diarrhea). For the infections of category II, the role of sanitation improvement is to interfere with the efficiency of the longer cycles and thus obtain a greater overall benefit than that possible for category I, in which these longer cycles have little significance.

Category III

This category contains the soil-transmitted helminths, which are both latent and persistent (see figure 2-4). Their transmission has little or nothing to do with personal cleanliness because these helminth eggs are not immediately infective to man. Domestic cleanliness is relevant only as it concerns the preparation of vegetables grown in fields enriched by human excreta or the maintenance of latrines in conditions that do not allow helminth eggs to remain in the vicinity for the duration of their latency. If eggs are not deposited in soil, or other suitable media, transmission will not occur. Any kind of latrine that contains or removes excreta and does not permit contamination of the floor, yard, or fields, will therefore limit transmission. Because the persistence of helminth eggs is so long (see table 2-3), it is not sufficient simply to prevent infected fresh feces from reaching the yard or fields: any fecal product that has not been adequately treated must not reach the soil. In societies that reuse their excreta on the land, treatment prior to application is therefore vital. Effective treatment for the removal of helminth eggs generally requires waste stabilization ponds or thermophilic digestion,[4] although prolonged storage will inactivate the eggs of many species.

Category IV

Category IV is for the beef and pork tapeworms. Any disposal system that prevents untreated human excreta from being eaten by cattle and pigs will control the transmission of these infections (see figure 2-5). Cattle are likely to be infected in fields treated with sewage sludge or effluent and may also eat feces deposited in the cowshed. Pigs are likely to become infected by eating human feces deposited around the dwelling or in the pigpen. The provision of toilets to which pigs and cattle cannot have access, and the treatment of all wastes prior to land application, are the necessary control methods. Measures to prevent birds, especially gulls, from feeding on trickling filters and sludge drying beds and subsequently depositing tapeworm eggs in their droppings on pastures are also required. In the absence of the measures described above, however, the thorough cooking of beef and pork is the most important control measure. Personal and domestic cleanliness, except the use and maintenance of safe toilets, are ineffective controls.

Category V

This category contains the water-based helminths, which need an aquatic host or hosts to complete their life cycles. Control is achieved by preventing untreated excreta or sewage from reaching water in which these aquatic hosts live (see figure 2-5). Any land application or dry composting system will therefore reduce transmission. There are two complications. First, in all cases except *Schistosoma mansoni* and *S. haematobium*, animals are an important reservoir of infection (see tables 1-9 and 2-3), and any measures restricted solely to human excreta can only have a partial effect. Second, in the case of *S. haematobium* it is the disposal of urine, far more difficult to control than the disposal of feces, that is important. Because multiplication of these helminths takes place in the intermediate hosts (except in the case of the fish tapeworm, *Diphyllobothrium*), one egg can give rise to many infective larvae. A thousandfold multiplication is not uncommon, and effective transmission can continue at low contamination levels. The requirements for adequate excreta disposal, in terms of the percentage of all feces reaching the toilet, may therefore be demanding.

4. See the discussion of these processes in chapters 5 and 6.

Category VI

The excreta-related insect vectors of disease form three main groups. In the first of these, the cosmopolitan *Culex pipiens* complex of mosquito species preferentially breeds in highly contaminated water and is medically important as a vector of the worm (*Wuchereria bancrofti*) that causes Bancroftian filariasis. The other two groups, flies and cockroaches, proliferate where feces are exposed. Both have been shown to carry numerous excreted pathogens on their feet and in their intestinal tract, but their role in actually spreading disease from person to person is disputed (though their nuisance value is certain). Flies have been implicated, however, in the transmission of eye infections and in infecting and spreading skin lesions. The control measures implied for insects are those sanitary improvements of differing sophistication which prevent their access to excreta. In general, the simpler the facility, the more care is needed to maintain it insect-free. Cockroaches, flies, and *Culex pipiens* mosquitoes often have breeding places in addition to those associated with excreta disposal and will in many cases elude control by disposal improvements alone.

Summary

The correlation of the environmental features of the categories with the length and spread of transmission routes has been indicated in figure 2-5, and the discussion has emphasized the importance of complementary controls for most diseases. If excreta disposal alone is improved, however, likely control for each category is as follows:

Category	*Control*
I	Negligible
II	Slight to moderate
III	Moderate to great
IV	Moderate to great
V	Moderate
VI	Slight to moderate

The outstanding difference is between categories I and II, which depend strongly on personal and domestic cleanliness, and the other categories, which do not. The central changes necessary to control infections in categories III and IV are relatively simple—namely, the provision of toilets *which people of all ages*[5] *will use and keep clean*, and the treatment of fecal products prior to recycling on the land. The reason that reports on the effects of latrine programs often do not show a marked decrease in the prevalence of the infections in categories III and IV[6] is that, although latrines have been built, they have typically neither been kept clean nor been used by children or by adults when working in the fields.

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5. Of course babies and very young children are unable to use a toilet. Health education programs must include advice to mothers on how to dispose of their children's excreta in a suitably hygienic way.

6. See the next chapter and table 2-1.

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