23

Ascaris and Ascariasis

ASCARIASIS IS AN INFECTION of particular importance to those engaged in sanitation programs because it is extremely common in most parts of the world and because the eggs of the *Ascaris* worm are very persistent in the environment and difficult to eliminate by sewage or night soil treatment processes.

Description of Pathogen and Disease

Knowledge of the biology and epidemiology of ascariasis is extensive, and only a brief summary is presented in this section.

Identification

Ascariasis is a helminthic infection of the small intestine by the human roundworm, *Ascaris lumbricoides*. About 85 percent of infections are symptomless, although the presence of even a few worms is potentially dangerous. The earliest symptoms are a pneumonitis with cough, dyspnea, substernal pain, fever, moderate eosinophilia, and sometimes blood-stained sputum (which may contain larvae). This is known as Loeffler's syndrome. These symptoms begin 5–6 days after infection, usually last 10–12 days, and are caused by the *Ascaris* larvae migrating and developing.

Heavy burdens of adult worms in the small intestine may cause digestive disorders, nausea, abdominal pain, vomiting, restlessness, and disturbed sleep. Adult worms may be passed in the feces or by mouth. Serious complications, especially among children, include bowel obstruction (figure 23-1) or death due to the migration of the adult worms to the liver, gall bladder, or appendix and, rarely, due to perforation of the intestine.

Where the prevalence and intensity of infection are high, the nutritional consequences of ascariasis in an undernourished population may be considerable. It has been estimated that a child who has twenty-six worms may lose 10 percent of his total daily intake of protein. There is also evidence that ascariasis in children may contribute to vitamin A and C deficiencies. The effect on child growth of light *Ascaris* infections, and the nutritional benefits from regular deworming, are subjects of current debate and research (Freij and others 1979; Gupta and others 1977; Stephenson 1980; Stephenson and others 1980; Willett, Kilama and Kihamia 1979).

Diagnosis is by microscopic identification of the eggs in the feces. The number of eggs counted gives an indication of the number of adult worms present.

Occurrence

Ascariasis occurs worldwide and especially in warm climates and among poor people. It is one of the most prevalent human helminths and infects 700–1,000 million people. Prevalence and intensity of infection are particularly high in preschool and young school children, among whom prevalences of 60–90 percent are reported. The fatality rate is about 0.02 percent and higher in children.

Infectious agent

A. lumbricoides, a nematode, is the roundworm of man. Females are 200–400 millimeters in length, whereas males are 150–300 millimeters (figure 23-1). The fertile eggs are ovoid and measure 45–70 micrometers by 35–50 micrometers. The pig roundworm, *A. suum*, closely resembles *A. lumbricoides*. There is evidence that *A. suum* may occasionally develop to maturity in man and that the larvae can cause pneumonitis even if the parasite does not mature. Several of the studies on *Ascaris* egg survival reported here use *A. suum* eggs because they are more readily available. The identical appearance of the eggs of *A. lumbricoides* and *A. suum* has almost certainly

Figure 23-1. Ascaris *in situ*. Shown is the small intestine of a person who died from intestinal obstruction caused by large numbers of entangled *Ascaris* worms. (Photo: Wellcome Museum of Medical Science)

confused some of the environmental studies of ascariasis in communities where domestic pigs are numerous.

Reservoir

The reservoir of *A. lumbricoides* is man. Pigs and dogs may disperse the undeveloped eggs of *A. lumbroicoides* by eating them in human feces and excreting them later at another place.

Transmission

Female worms lay up to 200,000 eggs per day. The unsegmented, fertilized eggs are passed in the feces. About 15 percent of the excreted eggs are infertile, and these are longer and narrower than the fertile eggs. They occur either because rapid production of eggs allows some to pass through unfertilized or because only female worms are present.

The first-stage larva in the egg must moult to produce a second-stage larva before the egg is infective. The proportion of eggs that develop and the time of development will depend on environmental conditions. Under ideal conditions of moist, shady soil at 22–33°C, a minimum of 10–15 days is required for about 75 percent of freshly passed eggs to become infective. Unfavorable conditions will retard development or may even interrupt it completely—to be recommenced on return to a favorable environment. Infective eggs can survive for long periods, and 7 years survival in soil has been recorded. During these long periods, eggs may be widely dispersed from the site of original defecation.

When the infective eggs are ingested—on hands, food, utensils, dust, and so forth—the larvae hatch in the duodenum. They are carried in the lymphatics or blood vessels, through the liver and heart, to reach the lungs in 3 days. The larvae develop further in the lungs, penetrate the air passages, ascend the trachea, are swallowed, and pass down the esophagus to reach the small intestine. They develop into adults in about 60–75 days and then live for up to 1.5 years.

The dominant vehicles for *Ascaris* egg ingestion are contaminated fingers, objects that have been placed on the ground (and can be sucked by children), dirt from the yard (that can be eaten by children) and contaminated vegetables. Waterborne transmission is possible but is of very minor importance. Infection may take place by the inhalation of eggs stuck to particles of wind-blown dust. This is especially likely in dry and windy regions or seasons. There is practically no firm evidence on the degree to which this mode of transmission takes place, and the subject has scarcely advanced since the early review by Lane (1934).

There is now a considerable body of evidence to indicate that ascariasis in highly endemic areas is a familial infection. Most transmission occurs when the house, floor, yard, or area around the house is contaminated by promiscuous defecation by small children. This contaminated soil then reinfects other children and adults in the same family. Visitors may also be infected. Infection is clustered by family and is strongly associated with soil contamination around a family's home.

Prepatent and incubation periods

The prepatent period (the interval between ingesting infective eggs and the appearance of eggs in the stools) is about 2 months.

The incubation period (the interval between ingesting infective eggs and the development of symptoms and signs of illness) varies from a few days (in the case of symptoms due to migrating larvae) to several months. The development of clinical illness depends upon the number of worms in the body and the state of health of the host. In many light infections in healthy people, no evidence of illness ever appears.

Period of communicability

Adult worms generally live for less than 10 months, with maximum life spans of up to 1.5 years. As long as mature fertilized female worms are living in the intestine, eggs will be passed in the feces.

Resistance

Susceptibility is general, but there is evidence of limited immunity. Some children experience decreasing worm burdens despite continuing exposure.

Epidemiology

Ascaris infection is extremely common in many countries, and there are many hundreds of reports on its prevalence in various communities. Surveys of 1–5 year old children in Guatemala revealed ascariasis prevalences of 46 percent among rural children, 26 percent among poor urban children, and 3 percent among more wealthy urban children (Pierce and others 1962). In one village in Guatemala, 93 percent of children had at least one *Ascaris* infection between birth and the age of 3 years (Mata and others 1977). Surveys of preschool children showed prevalences of 11 percent in Iran, 48 percent in Sri Lanka, 53 percent in Venezuela, and 69 percent in Bangladesh (van Zijl 1966).

A survey of 4–6 year old children in Kuala Lumpur (Malaysia) found a prevalence of ascariasis of 64 percent among poor children and 2.5 percent among "upper middle class" children (Yan and others 1978). It was noted that, in the poor communities, most adults (90 percent) did not know how these worms are transmitted and that children under 10 years old defecated indiscriminately around the houses because the rudimentary latrines available were unsafe for children to use on their own. A study of rural school children (6–12 years old) 72 kilometers from Kuala Lumpur found an 87 percent prevalence of ascariasis (Lo and others 1979). Sanitation facilities did not affect ascariasis prevalences among these children.

There are major unexplained variations among communities in the prevalence of *Ascaris* and in the relative prevalences of *Ascaris*, *Trichuris*, and hookworm. These may be related to soil types; it has been suggested that hookworm is especially common in areas of sandy soil, whereas *Ascaris* rates are highest in areas of fine silts and clays. Such theories appear to have no global validity. Climatic factors certainly influence egg development in the soil and, therefore, transmission. Temperatures of 20–32°C are ideal, with little development taking place below 18°C. A moist, shady environment also encourages egg development, and eggs may be killed or inhibited by desiccation or exposure to sunlight (Nolf 1932). Spindler (1929) concluded that the different moisture requirements of the eggs was the primary influence on the variation in the relative prevalences of ascariasis and trichuriasis and caused trichuriasis to be the more common in wetter areas, whereas the reverse was true in drier areas.

A study of the distribution of ascariasis in Tennessee (USA) concluded that the marked variations in prevalence were due neither to soil type, rainfall, nor temperature, but to behavior, and especially to the practice of defecating in the yard near the house (Otto, Cort and Keller 1931). Similarly, rainfall was found not to be a determining factor in *Ascaris* distribution in Panama (Cort and others 1929), nor soil type in Virginia (USA; Cort, Otto and Spindler 1930).

In areas where ascariasis is highly endemic, one of two distinct age distributions is found. In some communities there is a peak prevalence among children, typically 70–95 percent in the 5–9 age group, with prevalence gradually decreasing in older age groups to 10–50 percent among old adults. This pattern has been reported from China (Cort and Stoll 1931), Colombia (Faust and Mugaburu 1965), Haiti (Raccurt, Vial and Pierre-Louis 1977), Iran (Massoud and others 1980), Mexico (Biagi and Rodriguez 1960), Panama (Cort and others 1929), Papua New Guinea (Jones 1976*b*), and the USA (Cort, Otto and Spindler 1930; Schliessmann and others 1958). In other localities there is a high prevalence (typically 40–80 percent) in all age groups. This has been found in China (Cort and Stoll 1931), Iran (Ghadirian and others 1973; Mobedi, Arfaa and Movafegh 1971; Sahba and Arfaa 1967), Japan (Kutsumi 1969), Philippines (Cabrera, Arambulo and Portillo 1975), South Korea (Seo and others 1969; Soh 1973) and Tunisia (Thiers, Lassoued and Abid 1976).

Possible explanations for these two patterns of age-specific prevalence are differences in the parasites or in host reactions. Geographical differences in the parasites or in immune responses to childhood infection are theoretically possible although not recorded. Immune response differences between racial groups are an unlikely explanation because both patterns have been found in a single racial group (for instance, in China—Cort and Stoll 1931). It is more likely, therefore, that the two patterns of age-specific prevalence derive from differences in exposure due to differences in behavior, housing, agricultural practice, sanitation, and other environmental and cultural factors. Cort and Stoll (1931) suggested that the heavy and common infection of adult males with *Ascaris* in some parts of China was due to the intensive use of human feces in agriculture.

Several surveys, for instance in Virginia (USA; Cort, Otto and Spindler 1930) and Panama (Cort and others 1929), have revealed a somewhat higher prevalence of infection in women than in men. This difference is not seen in children. If the main source of infection is eggs deposited by infected children around the house, women may be more exposed because they spend more time than men working in the yard and tending to children. If vegetables fertilized by night soil are a major source of infection, women may also have greater exposure if they are responsible for their harvesting, cleaning, and preparation.

Ascariasis is common in some developed countries. There are an estimated 4 million people infected in the USA, with the disease being especially common in the southeast (Warren 1974). As in other countries, infection rates are highest among children, and there are about 2 cases of intestinal obstruction caused by ascariasis per 1,000 preschool children per year there; 3 percent of these cases of obstruction die (Blumenthal 1977). In the poorer parts of the USA it has been noticed that, whereas the wearing of shoes has caused a considerable decline in hookworm prevalence, *Ascaris* and *Trichuris* remain common (up to 60 percent of schoolchildren infected) owing to a lack of adequate improvements in sanitation and hygienic behavior (Fulmer and Huempfner 1965).

Intensity of infection (the number of worms living in the intestine) is quite as important in the epidemiology of ascariasis as prevalence (the proportion of persons having at least one worm). Heavy infections have more serious clinical consequences and are the infections most likely to be seen at clinics. In addition, persons with heavy infections are excreting huge numbers of eggs (up to 200,000 per female worm per day) and are therefore causing considerable potential for transmission. Individual egg outputs of up to about 300,000 per gram of feces are reported; assuming 100 grams of feces per day, this suggests at least 150 mature female worms in the intestine. The ratio of male to female worms in the intestine varies from about 0.3 to 1.

Children have higher egg outputs, owing to greater intensity of infection, than adults. This applies in both the age-specific prevalence situations described above. Thus, whether or not prevalence falls with age, intensity does, and this suggests an immune response that does not prevent infection but limits the intensity of infection by reducing the proportion of ingested eggs that develop into mature adults. Women may have higher egg outputs, indicating heavier infections, than men, which may be explained by the greater exposure of women discussed above.

A fundamental influence on the epidemiology of ascariasis is that a small minority of infected people are excreting the majority of the eggs. In China it was found that 5 percent of those infected excreted half of all eggs (Cort and Stoll 1931). Heavy infections tend to be single-brood infections. In other words, they are not an accumulation of worms from eggs ingested regularly over several months; rather, they are worms of a single age arising from the ingestion of a batch of eggs at one time. This may be due to an immune mechanism triggered by adult worms in the intestine and acting against the migrating larvae resulting from subsequent egg ingestions. More research is required in this area.

Not much is known about the seasonality of ascariasis. During a pronounced dry season transmission may decrease because the *Ascaris* eggs are desiccated in the dry soil. Therefore, there may be few new infections, and these will tend to be light. Since natural death is occurring among adult worms, intensity of infection, and possibly prevalence, will fall during the dry season. Transmission may increase with the rains and may cause an increased intensity, and possibly prevalence, about 2 months later. These climatic factors may be reinforced or negated by other seasonal changes, such as agricultural and dietary practices, that may influence exposure and resistance to infection. A November–December peak in transmission in Korea was attributed to contaminated pickled vegetables (Seo, Cho and Chai 1979).

The climatic influence on transmission described above might cause a pronounced seasonal pattern in intensity of infection (mean egg output) but little change in prevalence. Studies in Colombia (Faust and Mugaburu 1965), Panama (Cort and others 1929), and Taiwan (Chen and Hsieh 1969) have confirmed this seasonal picture. Seasonality in transmission may also lead to a seasonal peak in pneumonitis associated with *Ascaris* larvae migration, as has been reported from Saudi Arabia (Gelpi and Mustafa 1967).

There are three primary contexts for *Ascaris* transmission:

- Transmission in yards and compounds that have been contaminated by feces, especially those of children
- Transmission to persons working in fields where night soil or sewage is used as fertilizer
- Transmission to persons consuming vegetables that have been grown in fields enriched with night soil or sewage.

Yard transmission is probably the dominant mode in areas of poverty and inadequate sanitation. Families with heavily polluted yards tend to have high prevalences and intensities of ascariasis, and ascariasis is typically clustered by household. Familial aggregation of ascariasis has been reported from China (Winfield 1937), Tennessee (USA; Otto, Cort and Keller 1931), Virginia (USA; Cort, Otto and Spindler 1930; Hendley, Williams and Burke 1973), and Panama (Brown 1927; Cort and others 1929). The studies in Tennessee and Virginia also suggested that children from households with good sanitation could become infected when they visited heavily infected families and that rural schools with inadequate sanitation and heavy soil pollution acted as dissemination points for ascariasis in the community. *Ascaris* eggs were recovered in Egypt from the playgrounds of schools with no latrines, or with poorly maintained latrines, but not from schools with well-maintained latrines (Chandler 1954).

The pattern of yard contamination and infection may be modified by coprophagous domestic animals. Chickens, cats, and dogs in Tennessee (USA) were all found able to ingest *A. lumbricoides* eggs and to pass a proportion of them unharmed in their feces (Otto, Cort and Keller 1931). Pigs are enthusiastic consumers of human feces and may be especially important in distributing human *Ascaris* eggs. Jones (1976*a*) suggested that pigs in Papua New Guinea may play a role in transporting *Ascaris* eggs into villages, or even into homes, from human defecation sites that are often in thick undergrowth away from dwellings.

Transmission may take place not only in the fecally contaminated yard, but also in the home if the floor is made of a material that will permit the maturation of *Ascaris* eggs. Brown (1927) found that eggs deposited by small children onto hut floors in Panama developed to maturity in 14 days. Viable eggs have also been isolated from house floors in China (Winfield 1937) and Egypt (Chandler 1954). Studies in the USSR found that *Ascaris* eggs could develop on household objects and in floor cracks if humidities were high, and could remain viable for over 3 months in cool, humid environments such as cellars (Barchenko 1955).

The other two contexts for transmission mentioned above, transmission in the fields and via contaminated vegetables, are prominent either where feces are much used in agriculture or where hygiene is improved to the point at which yard transmission becomes relatively unimportant. The role of field infection has been much stressed in the Chinese literature, whereas both fields and contaminated vegetables are emphasized by workers in Japan, Korea, Taiwan and neighboring areas. The importance of vegetable contamination as a single factor has been stressed by writers from countries in which a well-educated and moderately wealthy population lives near to, and buys vegetables from, a poor community with endemic ascariasis; prominent examples in the literature are Israel, South Africa, and parts of the USSR.

The very high prevalences of ascariasis around Darmstadt (Federal Republic of Germany) in the late 1940s were due to the widespread practice of applying untreated sewage and sludge to fields and vegetable gardens (Baumhogger 1949). The prevalence of ascariasis among the Jewish population of Jerusalem decreased from 35 percent in the period 1934–47, to 1 percent in the period 1947–60. The decrease was attributed to the cessation of supplies of sewage-irrigated vegetables from Jordan after the partition of the city in 1948. In contrast, the prevalence of ascariasis in the Jordanian section of Jerusalem remained high, at 78 percent, in the early 1950s (Ben-Ari 1962). Khalil

(1933) documented a 96 percent prevalence of ascariasis among 5–16 year old children in the oasis of Siwa (Egypt) and attributed this to use of human wastes in agriculture.

Workers in formal sewage farms or sewage effluent irrigation schemes are also exposed to increased risk of *Ascaris* infection (Clark and others 1976). A study in Germany during 1954–56 showed ascariasis prevalences of 3 percent among sewermen, 16 percent among sewage treatment plant workers, 30 percent among sewage irrigation workers, and 8 percent among a control group (Sinnecker 1958).

This section is concluded by citing the account by Winfield (1937) of ascariasis in northern China in the 1930s. Each house had a combined animal shed and pit latrine. This comprised a pit, 3–5 meters square and about 2 meters deep, lined with brick or stone and with a base of tamped lime and clay, so that the whole pit was fairly watertight. The family defecated into the pit and also placed animal manure, organic refuse, and slops in the pit. Field earth was added at the rate of about one basketful per day. During dry weather, water was added to keep the pit contents wet; in the rainy season, the pit contained standing water and was the site of mosquito breeding. Adjacent to the pit was a shed where pigs and other animals were housed. Steps led down into the pit to allow the pigs to enter to eat fresh feces and to wallow in the muck. Usually the pit was emptied every spring and the waste was piled along the streets or on the village threshing floor. After a few days the waste was carted to the fields and placed carefully about the roots of the winter wheat or worked into the ground in preparation for the spring crop. Some families emptied their pits more than once a year, in which case the waste would be piled along the streets with a layer of straw-reinforced mud as a protective cover. It would then be used at the time of the next spring sowing.

Ascaris infection was very common, especially in those families having contaminated yards. *Ascaris* eggs were readily found in samples of soil from yards, floors and streets. Winfield concluded that fecal contamination of the yards and floors was the dominant cause of transmission and that contaminated water and vegetables were unimportant (see also Winfield and Yao 1937). Yard and floor contamination were caused by the casual defecation of children, who tended not to use the latrines because of inconvenience and fear of the pigs. *Ascaris* eggs were also distributed in the yards by chickens and dogs that fed on human excreta, both in the latrine and elsewhere. Contamination of the yard also occurred during the periodic emptying of muck from the pit for transport to the fields.

Control Measures

Only environmental and behavioral changes can have a sustained impact on ascariasis, but mass chemotherapy may be used to reduce infection rates in the short term.

Individual

No vaccines or prophylactic drugs are available. Individual protection can be obtained by scrupulous personal hygiene and care in choice and preparation of food, especially vegetables.

The most immediately effective method yet applied in areas with high prevalence is mass chemotherapy. The administration of appropriate drugs (such as levamisole, mebendazole, or pyrantel pamoate) to all individuals, or to all children, at regular intervals has dramatically reduced prevalences in several local trials. Mass treatment should start at the period in the year when worm burdens are highest and should ideally be repeated at intervals of not more than 60 days for as long as infective eggs remain in the soil. In most regions it would be impossible to prevent the reintroduction of infection following a mass treatment program, and therefore it is unlikely that mass treatment will be effective in the long term without concurrent improvements in excreta disposal and hygiene. In the absence of these preventive measures, prevalence may return to pretreatment levels within 6–12 months, although intensities (as measured by mean egg output) take somewhat longer to build up again. Literature on mass chemotherapy and reinfection in various countries is listed in table 23-1.

Environmental

Transmission of ascariasis generally occurs following the contamination with feces of the house floors, the yard, or the area around the house. Eggs develop to the infective stage and reinfect a child or adult who accidentally ingests a particle of contaminated soil or dirt. In areas of high prevalence, there is good evidence that most infection takes place in, or close to, the house and is clustered by family. Eggs are deposited primarily by small children who may defecate promiscuously in or near the home. Eggs may also be deposited by pigs, dogs, or chickens that have fed on human feces and can pass the human *Ascaris* eggs unharmed in their own feces.

This kind of family-centred transmission can be controlled, in theory, by providing a hygienic toilet *for all members of the family* and by providing the necessary

Table 23-1. *Some studies on the reduction and subsequent rise of ascariasis prevalence following mass chemotherapy*

Country	*Drug*	*Source*
Colombia	Pyrantel pamoate	Spillmann (1975)
India	Tetramisole	Gupta and others (1977)
Iran	Piperazine Levamisole Levamisole	Arfaa and others (1977) Arfaa and Ghadirian (1978) Massoud (1980)
Mexico	Piperazine	Biagi and Rodriguez (1960)
Panama	Tetrachlorethylene and chenopodium	Cort, Schapiro and Stoll (1929)
Philippines	Pyrantel pamoate Piperazine Levamisole	Cabrera, Arambulo and Portillo (1975) Garcia and others (1961) Jueco and Cabrera (1971)
Réunion (Indian Ocean)	Thiabendazole L-tetramisole	Coumbaras and others (1976)
Taiwan	Piperazine	Chen and Hsieh (1969)
Thailand	Pyrantel pamoate	Bhaibulaya and others (1977)
USA	Piperazine	Atchley, Wysham and Hemphill (1956)
Zaire	Levamisole	Jancloes, Cornet and Thienpont (1979)

health education to ensure that the toilet is used. Because children are the main excreters of *Ascaris* eggs, it is essential that any toilets should be acceptable and appropriate for use by children. In addition, it is necessary to clear up the stools of babies who are too young to use a toilet. Fresh stools are not immediately infective for *Ascaris*, and so they may be cleaned up any time up to a few days after deposition and still interrupt *Ascaris* transmission—except that delay in clearing up will increase the risk of dispersion or ingestion of eggs by domestic animals.

Improvements in excreta disposal facilities, defecation behavior, and child care can greatly reduce transmission. Bearing in mind that adult worms die naturally after 6–18 months in the small intestine, reduced transmission will cause a gradual fall in intensity of infection followed by a gradual fall in prevalence. Because the domestic environment may be heavily contaminated with *Ascaris* eggs that may remain infective for many months, transmission will continue for some time after sanitation has been improved, and there may be a considerable lag before reduced intensities and prevalences are measurable. There will be an even greater lag before reduced infection reaches a level at which it is apparent to mothers. This delayed response to reduced transmission is undesirable from a clinical viewpoint and will tend to decrease community enthusiasm for the preventive measures being advocated. It is for this reason that a combination of mass chemotherapy and sanitation is the best approach to ascariasis control.

In a combined program of mass chemotherapy, sanitation, and education the role of sanitation and education is to maintain the low intensities and prevalences created by the mass chemotherapy. This should be perfectly possible, and in recent years several East Asian countries have achieved notable success in ascariasis reduction by this approach. South Korea has had mass campaigns for the prevention of ascariasis including health education, stool examination and mass chemotherapy. Latrines have been widely provided. In 1949, the national prevalence of ascariasis was 81 percent, but by 1971 it was 46 percent (Soh 1973). These measures were also effective against trichuriasis (from 87 to 47 percent) and hookworm (from 39 to 7 percent).

There is no doubt that behavior is all important in the success of an excreta disposal program. Poorly used and maintained latrines will achieve little and may even increase transmission. Children may continue to defecate around the home and transmit eggs to their siblings. Even if excreta disposal is improved around the home, it may be unaffected in the fields, work places, or schools, where transmission may continue unchecked. Following studies in southwestern Virginia (USA) in 1928, Cort, Otto and Spindler (1930) wrote:

Several groups of negroes, one of which was extremely poor, as well as numbers of poor white families showed little or no *Ascaris* infestation because of the control of the children and the use of the privies by all members of the families. On the other hand some of the better-off rural families with well-kept yards and good privies and certain families in very well-sanitated mining camps had heavy infestations. Such infestations were almost always due to soil pollution near the houses by the young children, who were not taught to use the sanitary facilities provided.

Similarly, following work in China, Cort and Stoll (1931) wrote:

It was of interest to find one group in the Yangtze delta with a comparatively low infestation with both parasites [*Ascaris* and *Trichuris*] associated with a good economic status and habits of cleanliness much better than the average for rural China. This shows that human infection with these parasites can be much restricted even where their eggs are spread widely by the use of human feces as fertilizer.

The application of untreated nightsoil or sludge to the land undoubtedly contributes to *Ascaris* transmission. People working in the fields may be infected, and eggs may be brought into the home on soiled vegetables. Undeveloped eggs brought into the home can subsequently become infective if they end up on an earth floor or in a moist cranny. This route of infection is likely to be of minor importance where prevalence and intensity are high and where transmission is occurring primarily around the house. However, in areas where domestic hygiene is relatively good and toilets are used, contaminated crops may be the major route by which eggs are introduced into the household. Control of this agricultural transmission route is by adequate treatment of sludge and night soil prior to land application.

Studies on the environmental control of ascariasis are listed in table 23-2; more details of some of them are given in table 2-1. In most studies confounding variables were not adequately controlled, and it is not possible to separate the effect of sanitation, for instance, from that of socioeconomic and educational changes. Sanitation appeared to have an influence on ascariasis prevalence in some communities in Costa Rica, Egypt, Germany, Iran, Singapore, South Korea, and the USA, but it appeared to have little or no influence in Egypt, Panama, and the USA. Treatment of night soil, by heat or chemical ovicides, was effective in controlling ascariasis in some communities in Japan and the USSR.

Cases in which sanitation appeared ineffective are most probably due to insufficient use of, or to poor hygiene in, the latrines or to transmission continuing away from the home at the place of work or recreation. Unfortunately, most studies do not clearly demonstrate this because they are deficient in behavioral observations. Constructing latrines and measuring health changes does not provide the data necessary to explain any impact, or lack of impact, observed. Detailed observations of actual use of latrines, especially use by children, are required but are very seldom carried out. Also rare are studies on traditional beliefs and practices concerning ascariasis—such as that conducted in rural west Malaysia by Chen (1970)—which can be invaluable in the design of health education campaigns to accompany sanitation and mass chemotherapy programs.

In conclusion, it is sobering to consider two statements made half a century ago, which remain true but sadly ignored today. Otto and Spindler (1930) wrote:

The building of privies is a fundamental step in the control of infectious diseases spread by soil pollution, but to be successful they must be used exclusively. In the regions just discussed [Virginia] the situation is difficult because many of the people are doubtful of the value of a privy. In many cases they feel that it produces an unwise accumulation of odorous and obnoxious waste which if daily dropped in various parts of the yard would be destroyed by insects or chickens and washed into the soil by the rains. Those adults who do consent to build and use the privy often do not feel sufficiently convinced of its beneficial results to take any time to teach the young children to use it. Furthermore, as has already been pointed out, the pit privy as usually built is structurally ill adapted to children's use and frequently inconveniently situated. The seat is too high and the hole too large to be conveniently and safely used by young children. A lower seat or a step to part of the main seat with a smaller hole for the convenience of young children should certainly be encouraged. The real problem, however, is the slow process of educating these people to consider the sanitary privy as one of the most

Table 23-2. *Some studies on environmental influences on ascariasis*

Country	*Result*	*Source*
Costa Rica	Ascariasis prevalence was lower among those with improved sanitation	Moore, de la Cruz and Vargas-Mendez (1965)
Egypt	A village receiving improved water supplies, latrines, and refuse collection had a lower prevalence (50 percent) and intensity (4,200 eggs per gram) of ascariasis than a village with unimproved sanitation (prevalence = 76 per cent; intensity = 6,900 eggs per gram)	Chandler (1954)
	Ascaris rates remained high among prisoners, despite falling rates of hookworm and schistosomiasis, owing to regular reinfection by contaminated vegetables grown on the prison sewage farm	Khalil (1926, 1931)
	Improved sanitation, with and without chemotherapy, did not reduce ascariasis in several villages	Scott and Barlow (1938)
Germany	Prevalences of ascariasis in schoolchildren in Berlin were 3 percent in sewered areas, 7 percent in unsewered rural areas, and 14 percent in unsewered urban areas	Anders (1954)
Iran	Water and sanitation improvements had little impact on prevalence but considerable impact on intensity of ascariasis; water and sanitation improvements plus regular mass chemotherapy added nothing to the impact of mass chemotherapy alone	Arfaa and others (1977)
	Prevalence of ascariasis was the same among people with and without sewerage in Isfahan	Sadighian and others (1976)
	Water supply, sanitation, and bathing improvements were associated with a fall in prevalence (67 to 57 percent) and intensity (11,000 to 4,000 eggs per gram) in a single village	Sahba and Arfaa (1967)
Japan	Heat treatment of night soil prior to agricultural application was associated with a declining prevalence of ascariasis	Katayama (1955)
	Heat treatment of night soil had little effect on ascariasis but was effective in maintaining a lowered prevalence achieved by mass chemotherapy	Kawagoe and others (1958)
	Night soil treatment with sodium nitrite and calcium superphosphate reduced but did not prevent rising prevalence of ascariasis following mass chemotherapy	Kozai (1960*a*, 1960*b*, 1960*c*, 1962)
	Night soil treatment with thiabendazole reduced ascariasis prevalence by 30 percent over 2 years and night soil treatment plus mass chemotherapy reduced it by 50 percent	Kutsumi (1969)
Panama	Sanitation did not delay reinfection following mass chemotherapy	Cort, Schapiro and Stoll (1929)
Singapore	Poor families rehoused in modern flats had an ascariasis prevalence of 9 percent compared with that of squatters (63 percent)	Kleevens (1966)

Table 23-2. (*continued*)

Country	*Result*	*Source*
South Korea	Higher intensities of ascariasis occurred in poorer parts of Seoul using vault latrines than in wealthier areas with sewerage	Soh and others (1973)
USA		
Kentucky	Ascariasis prevalence was associated with both water supply and sanitation facilities	Schliessmann and others (1958)
Tennessee	Ascariasis prevalence was associated with sanitation, fecal contamination, domestic and personal cleanliness, family size, but not water quality	Eyles, Jones and Smith (1953)
	Pit latrines were not effective in reducing ascariasis because they were commonly not used by children, who defecated in the yard	Otto, Cort and Keller (1931)
Virginia	Pit latrines were not effective in reducing ascariasis because they were commonly not used by children, who defecated in the yard	Otto and Spindler (1930)
USSR	Cessation of use of untreated night soil as a fertilizer was associated with a marked decrease in *Ascaris* egg contamination of soil and fruit	Rosenberg (1960)

necessary buildings on the premises of every family and its use taken as a matter of course. When this is accomplished, and not until then, will human excreta be so disposed as to protect not only against *Ascaris* infestation but against bacterial diseases as well.

Cort (1931) wrote:

In many places *Ascaris* infestation has been reduced or eliminated by sanitary programs carried out over long periods of time, especially where other factors have raised the social and economic level of the population. It has been shown, however, that very frequently sanitary work has not been successful in controlling this parasite because of the failure of young children to use the facilities provided. For *Ascaris* control, therefore, it is necessary to provide facilities well adapted for children's use and to concentrate the educational program on the prevention of soil pollution by young children. Since the presence of this parasite in both cities and rural communities over such wide areas of the world can be used as an index of the status of sanitation it seems that campaigns for its control might form a larger part than at present of programs for the improvement of sanitary conditions.

Occurrence and Survival in the Environment

Ascaris eggs may be the most hardy and resistant of all excreted pathogens. They can survive a variety of environmental conditions for periods of months or even years. They need small quantities of oxygen to develop but can remain viable for long periods in anaerobic conditions.

In surface water

The occurrence and survival of *Ascaris* eggs in waters is not a very important subject because little or no transmission is waterborne.

Usacheva (1951) found *Ascaris* eggs in a high proportion of river water and river sediment samples in the USSR. All samples contained *Ascaris* eggs at times of flooding. Survival experiments revealed that 12 percent of eggs in river water, and 17 percent of eggs in sediment, were viable after 15 months (presumably the temperatures were cool). Goryachev (1947) also isolated *Ascaris* eggs from river water and sediment near Omsk and found more in winter than in spring.

Iwańczuk (1969) found, on average, 0.8 *Ascaris* eggs per 100 grams of soil at six public beaches on the shores of the River Vistula in Poland. The largest number of eggs and the most advanced in development were found in the damper zones, such as the water's edge, in the shade of bushes, and near public toilets. The beaches were not close to sewage outfalls and it is probable that most eggs came from defecation by beach visitors, rather than from the river water.

Ascaris eggs are especially likely to occur directly downstream from sewage outfalls. Near Denver (Colorado, USA) a river contained 0–1 eggs per liter above a sewage outfall, and 0–14 per liter below it. *Ascaris* eggs were also recovered 3 kilometers downstream from the outfall (Wang and Dunlop 1954).

In groundwater

Ascaris eggs are unlikely to occur in groundwater because their size causes them to be retained as polluted surface waters percolate down through porous strata. They may, however, occur where surface waters are flowing directly into groundwaters via fissures in metamorphic rocks or solution channels in limestone.

In drinking water

No reports of *Ascaris* eggs in drinking water have been found. As mentioned above, their presence is of little interest because waterborne transmission is unimportant relative to yard and field transmission. Chlorine and chloramine are completely ineffective against *Ascaris* eggs at, or even greatly above, the concentrations typically applied during water treatment.

Ascaris eggs were found in the raw river water supplying Ufa (USSR) but not in the tap water (Bukh 1945).

In seawater

Yarulin (1955) found *Ascaris* eggs in the coastal waters of the Caspian Sea near sewage outfalls. Eggs remained viable for considerable periods in seawater but did not develop until removed. Laboratory experiments in South Africa found that 97 percent of *Ascaris* eggs were killed after 2 days in seawater. They were considerably more resistant than *Trichuris*, hookworm, or *Enterobius* eggs, but somewhat less resistant than *Taenia* eggs (Livingstone 1978). The specific gravity of *Ascaris* eggs is about 1.11, and so they will settle in seawater and in seawater and sewage mixtures with specific gravities of 1.00 to 1.03.

In feces and night soil

The high prevalence of *Ascaris* egg excretion in some communities has been described above in the section on epidemiology. Some individuals excrete large numbers of eggs, up to 300,000 per gram of feces, and thus night soil may be rich in *Ascaris* eggs. If the prevalence is 60 percent, the mean egg output of those infected 10,000 eggs per gram, and the mean night soil volume of 2 liters per capita daily, then the night soil will contain 3×10^7 eggs per liter. Concentrations this high have not been reported. Night soil in Kiangsu Province (China) contained 2.3×10^6 *Ascaris* eggs per liter (McGarry and Stainforth 1978).

Takenouchi and others (1980) studied *Ascaris* eggs in night soil in Kochi Prefecture in Japan. *Ascaris* egg concentrations were higher in night soil from mountain areas than from coastal regions, and it is suggested that the regular enumeration of *Ascaris* eggs in night soil is a useful method of monitoring ascariasis in the community.

Survival of *Ascaris* eggs for over 1 year is possible in feces and night soil. In anaerobic conditions development is arrested but recommences when air is introduced. Urine is ovicidal and will kill eggs in 16 hours. Eggs fail to develop in dilutions of urine down to 10 percent (Hamdy 1970*a*).

In sewage

Raw sewage has been reported to contain up to 38 *Ascaris* eggs per liter in eleven towns in the German Democratic Republic (Kalbe 1956); 10–80 per liter in Tokyo, Japan (Liebmann 1965); 38 per liter in San Juan, Puerto Rico (Rowan and Gram 1959); 5 to 110 per liter in Denver, USA (Wang and Dunlop 1954); and 19 per liter of settled sewage in Daspoort, South Africa (Nupen and de Villiers 1975). Wang and Dunlop (1954) reported that 87 percent of the eggs in raw sewage were viable.

Sewage from some communities in developing countries may be expected to contain much higher concentrations of *Ascaris* eggs than these. In Calcutta (India) 20,000 to 213,000 *Ascaris* eggs per capita per day were reaching the sewage works; assuming 100 liters of sewage per capita per day, this implies concentrations of 200–2,130 *Ascaris* eggs per liter (Bhaskaran and others 1956). Raw sewage in Aleppo (Syria) contained 1,000 to 8,000 *Ascaris* eggs per liter due to an estimated 42 percent of the population excreting, on average, 800,000 eggs daily per person (Bradley and Hadidy 1981).

In sludge

The effect of many sewage treatment plants is to concentrate *Ascaris* eggs in the sludge. In South Africa raw sludges contained 0–250 *Ascaris* eggs per gram (Keller and Hide 1951; Krige 1964). In the Johannesburg area, 74 percent of eggs in raw sludge were viable (Keller and Hide 1951). In Kharkov (USSR) raw sludge from the trickling filter plant contained 20–48 *Ascaris* eggs per gram (Vishnevskaya 1938). Near Moscow (USSR) the sludge from trickling filter plants contained up to 466 helminth eggs per gram (Vassilkova 1936).

Ascaris eggs were recovered from 6 to 95 percent of sludge samples collected from several sites in the USA and were the most frequently identified parasitic helminth (Theis, Bolton and Storm 1978). Sludge from Los Angeles (California) contained up to 100 *Ascaris* eggs per gram, but most sludges contained less than 50 per gram. An earlier study (Wright, Cram and Nolan 1942) found *Ascaris* eggs in 36 percent of sludge samples from seventeen army camps in the southern USA. *Ascaris* was the most frequently identified parasitic helminth.

Sludge in developing countries may contain a much higher concentration of *Ascaris* eggs. Trickling filter plant sludge in Isfahan (Iran) contained 18,100 eggs per gram (Sadighian and others 1976), and septic tank sludge in China contained 2,300 *Ascaris* eggs per gram (McGarry and Stainforth 1978).

In soil

Ascaris eggs are found in soil in fields where night soil or sewage are applied for fertilization or irrigation and in places used as defecation sites by infected people. *Ascaris* eggs will survive for several years in soil. The maximum recorded survival time is 7 years (Kirpichnikov 1963). Survival is promoted by cool, moist, and shaded soil and by being under the surface rather than on top. Exposure to sunlight and desiccation will reduce survival time very considerably.

Gärtner and Müting (1951*a*) studied land irrigated by sewage effluent in the Federal Republic of Germany. Samples were taken from land that had been irrigated 11 months earlier and from land irrigated only 4 to 6 days previously. There were many more *Ascaris* eggs present in the latter than in the former: in both cases the concentration diminished with increased depth. In no case did *Ascaris* eggs penetrate into the sand 0.3 meters beneath the cultivated soil. No *Ascaris* eggs were found on vegetables grown in sewage-irrigated fields. Rosenberg (1960) found that soil around a village in the USSR contained *Ascaris* eggs in 100 percent of samples; 41 percent of these eggs were viable. After cessation of fertilization with night soil, the proportion of positive soil samples fell to 35 percent, and no eggs were viable.

The survival times of *Ascaris* eggs in clean silty soil in the USSR were 23–29 days on the surface, up to 1.5 years at 0.1–0.2 meters' depth and over 2.5 years at 0.4–0.6 meters. In soil with sewage sludge, survival was for up to 1 year at 0.1–0.2 meters and up to 1.5 years at 0.4–0.6 meters (Drozdova and others 1973). In the Federal Republic of Germany *Ascaris* eggs in sewage irrigated fields survived for up to 1.5 years (Gärtner and Müting 1951*b*). In contrast, *Ascaris* eggs deposited on sewage irrigated pasture in South Africa were inactivated in a few days owing to rapid dessication (Keller and Hide 1951). The run-off water from the pasture contained no eggs. The work of Lýsek and his colleagues has suggested that fungi are instrumental in killing *Ascaris* eggs in soil, especially in the tropics (Lýsek 1964; Lýsek and Bačovský 1979).

Surface soil contamination with *Ascaris* eggs can be reduced by the use of subsurface irrigation methods. Romanenko (1969) studied subsurface irrigation with raw sewage via earthenware pipes laid at a depth of 0.6 meters, over a 9-year period. No *Ascaris* eggs were found in the surface layers of soil.

Night soil cartage systems may contaminate the soil of city streets and lanes with *Ascaris* eggs. Nineteen percent of soil samples collected from the streets of Isfahan (Iran) contained *Ascaris* eggs (Hoghooghi and others 1973). The soil contamination rate and the proportion of viable eggs were highest in winter and lowest in summer. Both of these parameters were directly related to the rainfall and inversely related to the air temperature.

On crops

As mentioned previously, the contamination of vegetables by *Ascaris* eggs may be an important transmission route in some communities where family-centered transmission is relatively unimportant, owing to improved sanitation and hygiene, but where night soil or sewage are applied to vegetable gardens. The subject was reviewed 30 years ago by Rudolfs, Falk and Ragotzkie (1950, 1951*a–c*).

The contamination of vegetables by *Ascaris* eggs, following the use of sewage, night soil, or sludge for fertilization, has been a major concern of parasitologists in the USSR for many years (Khaustov 1935). Vassilkova (1941) reported that cucumbers, tomatoes, and carrots, grown outside Moscow and irrigated with sewage, were contaminated by *Ascaris* eggs and that 36 percent of these were viable. On the basis of these findings she suggested that sewage irrigation should be discontinued before harvesting and that vegetables should be gathered directly into baskets and not laid on the ground. In a later study (Vassilkova 1950), she found that tomatoes and cucumbers irrigated with raw sewage contained about 20 eggs per 100 vegetables, whereas those irrigated with settled sewage contained about 3 per 100 vegetables.

In Lithuania, 98 percent of vegetables from gardens using raw sewage contained helminth eggs, compared with 9–16 percent of vegetables from other gardens and 7–11 percent of cleaned vegetables on sale in markets. Of all helminth eggs isolated from vegetables, 94 percent were *Ascaris*, 5 percent *Trichuris*, and 1 percent *Enterobius* (Biziulevicius 1954).

Rosenberg (1960) found that the proportion of fruit that was contaminated by *Ascaris* eggs in a village dropped from 71 percent to 25 percent following the cessation of use of untreated night soil in agriculture. No helminth eggs were detectable in samples of cucumbers, beetroot, potatoes, onions, and grass grown in fields irrigated by subsurface irrigation, whereas similar vegetables grown in fields irrigated by sewage flooding were heavily contaminated with viable *Ascaris*, *Trichuris*, and *Enterobius* eggs (Romanenko 1971).

There is less literature on this topic from countries other than the USSR, but substantial vegetable contamination may be expected where night soil or sewage is being used. In the USA, 6 percent of sewage-irrigated vegetable samples were contaminated with *Ascaris* eggs despite furrow irrigation, dry climate, sandy soil, and the fact that the sewage had undergone primary sedimentation and chlorination (Dunlop and Wang 1961).

In China and neighboring countries, where night soil is widely used for vegetable gardening, extensive *Ascaris* contamination of vegetables may be expected. Vegetable leaves in South Korea contained 38 eggs per 100 grams, and carrots had 0.6 eggs per 100 grams (Choi 1970). Early studies in northern China (Winfield and Yao 1937) suggested that vegetables were unimportant in *Ascaris* transmission. During 1933–34, 275 kilograms of vegetables from Tsinan market were examined. No eggs were found. Other vegetables were examined with the same result. Soil samples were collected from vegetable gardens, of which 57 percent were positive for *Ascaris* eggs. These data were held to substantiate the finding of Winfield (1937) that, although night soil compost was used to fertilize vegetables, contaminated vegetables were not an important transmission route. Most transmission occurred in and around the home.

In a humid environment and a shady site, *Ascaris* eggs can develop to the infective stage and survive for considerable periods on vegetables (Barchenko 1953). In an arid climate, and if exposed to sunlight, a combination of desiccation and ultraviolet irradiation causes more rapid death. Rudolfs, Falk and Ragotzkie (1951*a*) sprayed *A. suum* eggs onto growing tomatoes and lettuce under hot and dry conditions and found that they did not survive for more than 1 month.

Several studies have been conducted into methods of cleaning suspect vegetables prior to eating. In Czechoslovakia, Lýsek (1959) found that thorough rinsing removed *Ascaris* eggs but that wiping did not. In South Korea, Choi (1970) found that keeping vegetable leaves in water for 10 minutes, and then shaking them 20 times, removed only 40 percent of *Ascaris* eggs. Thitasut (1961) concluded that soaking vegetables in a solution of 100 milligrams per liter of iodine for 10 minutes would kill *Ascaris* eggs without damaging the vegetables. Zaman and Visuvalingam (1967) recommended 250 milligrams per liter of iodine for 10 minutes. Soh (1960) experimented with a wide range of pickling and food preservative substances (salt, sugar, vinegar, alcohol, bean sauce, garlic, mustard, onion, pepper, clove, allspice, cinnamon, and ginger) and found that none of them was strongly ovicidal. Rudolfs, Falk and Ragotzkie (1951*b*) concluded that immersing vegetables in warm water (60°C) for 10 minutes was the most reliable method of destroying *Ascaris* eggs.

The effect of vegetable decontamination on ascariasis was studied at a boys' school in Japan (Tomomatsu and Takeuchi 1961). *Ascaris* prevalence was originally 37 percent and fell to 5 percent following administration of a vermifuge. From that time, vegetable washing began using potassium iodide. After 5 months the prevalence had risen to 12 percent, and after 8 months to 16 percent. The authors claim that the rate of reinfection would have been greater if it had not been for the vegetable washing program, but there was no control group and they were unable to substantiate their claim.

Inactivation by Sewage Treatment Processes

Ascaris egg removal in sewage treatment processes is primarily a function of the degree to which sedimentation to the sludge layer takes place.

By septic tanks

In an experimental septic tank in India with 3 days retention time, 99.4 percent of *Ascaris* eggs settled. However, in operational septic tanks removal was far lower than this (Bhaskaran and others 1956).

An unpublished report from the United Nations Environment Program (UNEP 1976) described the effect on *Ascaris* eggs of the Chinese three-compartment septic tank. The retention time of each chamber was 15–20 days, assuming a daily inflow of 2.4 liters per capita. Each unit served a group of houses, and the contents of bucket latrines were emptied into it. Studies on *Ascaris* eggs indicated that 80–96 percent were retained in the first two chambers. Eggs accumulated primarily in the sludge in the first chamber (at about 3,000 eggs per gram), where 67–95 percent of them died if stored for 2 months. A different account of the Chinese three-compartment septic tank is given in McGarry and Stainforth (1978). The retention times in the three compartments were 10, 10, and 30 days, respectively. The contents of the first compartment were semisolid. specific gravity fell and egg sedimentation improved as the liquor passed through the second and third compartments. The effluent was free of *Ascaris* eggs. The sludge in the third compartment contained 2,300 eggs per gram, and all of these were judged on morphological grounds to be dead.

By conventional treatment

The effect of conventional sewage treatment plants is to concentrate *Ascaris* eggs in the sludge. A few may be found in the effluent, but sometimes they are absent (for intance. see Forstner 1960). Typical *Ascaris* egg reduction rates are 35–90 percent by primary sedimentation alone, 90–99 percent by a complete trickling filter plant, and 90–100 percent by a complete activated sludge plant (see Cram 1943; Feachem and others 1980; Kabler 1959; and the studies mentioned below).

At the Kharkov (USSR) trickling filter plant, raw sewage contained on average 60 *Ascaris* eggs per liter, after primary sedimentation 20, after trickling filter 13, and after secondary sedimentation 2 per liter (Vishnevskaya 1938). At two other treatment plants in the USSR, raw sewage contained the eggs of *Ascaris*, *Trichuris*, *Enterobius*, *Diphyllobothrium*, and *Taenia* at a concentration of up to 2,000 eggs per liter. Egg concentrations were reduced by 97 percent in Imhoff tanks, by 18–26 percent in trickling filters, and by 87 percent in secondary sedimentation tanks. Chlorination of the effluent had no effect. Predictably, sludge contained many helminth eggs: up to 466 per gram (Vassilkova 1936).

At the trickling filter plant in Daspoort (South Africa), the concentrations of *Ascaris* eggs per liter were 19 in the settled sewage, 1 in the trickling filter effluent, and 1 in the final effluent from the secondary sedimentation tank (Nupen and de Villiers 1975). In Denver (Colorado. USA) raw sewage contained 5–110 *Ascaris* eggs per liter, settled sewage 2–30, and chlorinated settled sewage 0–20. The relative persistence of *Ascaris* eggs versus coliform bacteria is illustrated by the egg to coliform ratios, which were 1:14.000,000 in raw sewage, 1:10,000,000 in settled sewage, and 1:7,000 in chlorinated effluent (Wang and Dunlop 1954). No loss of viability occurred in the treatment plant, and the proportion of viable eggs was 87 percent in the influent and 88 percent in the effluent.

Three types of sewage treatment works in Puerto Rico were investigated by Rowan (1964). Primary sedimentation plants removed 35–74 percent of *Ascaris* eggs, trickling filter plants removed 95–99 percent, and activated sludge plants 97–100 percent of eggs from the effluent. Typically, small numbers of *Ascaris* eggs (up to 1 per liter) could be recovered from the effluent of secondary settling tanks following either trickling filter or activated sludge treatment. It was expected that large numbers of eggs would have been found in the sludges from these treatment plants but this was not investigated.

The survival of helminth eggs was studied in five sewage works in and around Calcutta (India) over a 4-year period (Bhaskaran and others 1956). The average number of *Ascaris* eggs per capita per day reaching the sewage works ranged from 20,000 to 213,000. Far greater numbers of *Ascaris* eggs than hookworm or *Trichuris* eggs were found. Primary sedimentation for about 2 hours caused the settlement, on average, of around 70 percent of *Ascaris* eggs. *Ascaris* eggs settled more rapidly than those of hookworm or *Trichuris*. Removal of *Ascaris* eggs from the effluent of activated sludge plants was over 90 percent and was higher when the plant was well maintained and well operated.

Panicker and Krishnamoorthi (1978) summarized *Ascaris* egg removal by various treatment plants in India. Reductions were 96 percent after 2 hours primary sedimentation, 47 percent after 1.5 hours sedimentation, 98 percent by a complete activated sludge plant. 95 and 96 percent by two complete trickling filter plants, 79 percent by a pilot scale biodisc plant, 92 percent by a pilot-scale aerated lagoon without secondary sedimentation, and 94 percent by a pilot-scale oxidation ditch with secondary sedimentation (see table 22-4).

By waste stabilization ponds

A well-designed series of waste stabilization ponds, with 3 or more cells and an overall retention time of at least 20 days, removes all *Ascaris* eggs from the effluent. Eggs settle to the sludge layer where they die after a few months.

In India, 100 percent removal of *Ascaris* eggs was recorded in a three-pond system with total retention of only 6 days (Lakshminarayana and Abdulappa 1969), and Panicker and Krishnamoorthi (1978) found no *Ascaris* eggs in the effluent from four-pond systems.

Sewage in Dushanbe (Tadzhik SSR, USSR) was treated in four ponds (an anaerobic pond with area 2 hectares, depth 1.5 meters and retention time 10 hours, and three following ponds with area 4–4.5 hectares and depth 0.6 meters). The total retention time was only 33 hours. The effluent from the ponds was used to irrigate a rice paddy. Owing to the short overall retention time in the ponds, the quality of the effluent was not good (coliform count 10^6 per 100 milliliters; BOD_5 39 milligrams per liter). Inflowing sewage contained an average of 23 helminth eggs per liter, whereas the effluent contained none. Most eggs were removed in the first anaerobic pond (Koltypin 1969).

Ponds with short retention time may not remove all *Ascaris* eggs, especially during heavy rain or freezing conditions. Experiments in the Ukraine (USSR) found that two-cell ponds, with total retention of 3.6 days, let through *Ascaris* eggs in winter when the ponds froze and the increased velocities of flow along the base of the ponds picked up solids and eggs and carried them out in the effluent. An average of 0.5 *Ascaris* eggs per liter was found in the effluent in winter. A similar effect was experienced during heavy summer rain, which also increased the velocity of flow through the ponds (Ptitsyna 1966).

By tertiary treatment

Filtration through soil or sand should remove *Ascaris* eggs from sewage effluents. The retained eggs may develop to the infective stage and survive for many months.

Effluent chlorination is of no value in *Ascaris* removal. Chlorine and chloramine are ineffective against *Ascaris* eggs at, or greatly above, the concentrations typically applied to sewage. Low chlorine doses may even accelerate *Ascaris* egg development. (Iwańczuk and Dożańska 1957; Krishnaswami and Post 1968).

Inactivation by Night Soil and Sludge Treatment Processes

Ascaris eggs tend to become concentrated in the sludge of all sewage treatment processes, and high concentrations are found in night soil. Their removal from these materials is therefore of considerable importance. Unless extreme desiccation occurs or ovicidal chemicals are added, *Ascaris* egg destruction in night soil and sludge depends almost entirely on time and temperature.

By pit latrines

Ascaris eggs in pit latrines can survive for 1–2 years, especially if conditions are cool and wet and if the latrines are sealed with a covering of soil. Available data come from temperate regions, and it is probable that survival times will be shorter in warmer climates. In tropical and subtropical areas it can be assumed that pit contents will be free of viable *Ascaris* eggs after being sealed for 1 year, and the necessary period is probably less than this if the pit is in dry soil above the water table.

In early experiments in the USA, Stiles and Crohurst (1923) found that all *Ascaris* eggs died after being buried under sawdust for 38 months. Experiments on the viability of *Ascaris* eggs in pit latrines were conducted in the USSR with the object of determining the length of storage before the excreta could be safely employed for manuring fields and kitchen gardens. Experimental pit latrines were in constant use by workers of a state farm for a prescribed period of time, after which three were covered with boards and earth, while one was left open. Samples were removed once a month. When examined immediately after removal, the eggs were invariably unsegmented—indicating that they were not developing in the pit latrines. In the open pit all eggs were dead after 6 months. In the covered pits 97 percent died after 6–8 months, and 10–13 months were required for 100 percent destruction. Egg destruction was more rapid in summer, and complete *Ascaris* elimination was obtained by sealing the pit in early spring (February–March) and reopening in November. In feces diluted with water (1 : 1 by volume), survival was prolonged, and 95.5 percent of the eggs perished only after 20 months (Vassilkova 1940). More recent work in the USSR found that some *Ascaris* eggs in pit latrines survived for over 18 months and outlived *Trichuris* eggs (Biziulevicius 1965).

By biogas plants

The removal of *Ascaris* eggs in biogas plants depends on the retention time and the degree to which the design prevents short-circuiting of flow. Chinese data suggest that 2–7 percent of influent *Ascaris* eggs will appear in the effluent (Hou and others 1959; McGarry and Stainforth 1978; Szechwan Research Institute 1974). The eggs removed settle to the sludge layer, where they remain viable for many months. Studies in Szechwan showed that adding small amounts of waste frequently, improving design to reduce short-circuiting, and increasing the organic content of the influent all reduced the egg concentration in the effluent.

By digestion

Mesophilic digestion, or digestion at cooler temperatures, does not greatly reduce the concentration of *Ascaris* eggs in sludge (Kabler 1959). *Ascaris* eggs have been frequently isolated from digested sludge, for instance in the USA (Cram 1943; Fitzgerald 1981) and the USSR (Vassilkova 1936), and digestion periods far longer than normally employed are required before a significant *Ascaris* reduction can be obtained.

Experiments in India showed that 40 percent of *Ascaris* eggs held at 36°C for 50 days were still viable, and a few viable eggs could still be isolated after 150 days (Bhaskaran and others 1956). *A. suum* eggs were held for 21 days at 38°C in sludge from various sewage treatment works in the Chicago area (USA). With the exception of one sample, at least 46 percent of the eggs remained viable, and some were then found to be infective to pigs (Fitzgerald and Ashley 1977).

Cram and Hicks (1944) reported that 10 percent of *Ascaris* eggs in digesting sludge were viable after 6 months, and some were still viable after 1 year. Eggs previously embryonated appeared to be more susceptible to subsequent anaerobic digestion than undeveloped eggs. In Johannesburg (South Africa) raw sludges contained between 50 and 243 *Ascaris* eggs per gram, whereas digested sludges contained 105–552 per gram. The effect of sludge digestion in concentrating eggs was noted. However, 74 percent of eggs in raw sludge were viable compared with only 39 percent viable in digested sludge (Keller and Hide 1951). At Kouřim (Czechoslovakia) up to 100 percent of *Ascaris* eggs in raw sludge were viable, whereas only 58 percent in digested sludge were viable (Králová and Šafránek 1957).

Under anaerobic conditions eggs tend to stay alive but not develop. Under aerobic conditions and temperatures above 20°C, eggs develop and may become infective. Reyes, Krusé and Batson (1963) reported studies on aerobic and anaerobic batch digestions of night soil seeded with *A. suum* eggs. At low temperatures, both aerobic and anaerobic digestion tended to preserve eggs in a viable condition. In the 25°C–35°C range, both systems resulted in some egg destruction attributable to factors other than heat. Oxygen starvation in anaerobic digestion and spontaneous hatching in aerobic digestion may have contributed to egg destruction. At 30°C, viability was better maintained when eggs were kept in night soil than when they were kept in water. Complete egg destruction was not possible unless temperatures were maintained above 45°C in aerobic processes and 38°C in anaerobic processes.

A. suum eggs in swine wastes (2 volumes of pig feces plus 1 volume of pig urine plus 17–32 volumes of water) readily survived aerobic and anaerobic digestion for 68 days at 12°C (over 90 percent remained viable). At 22°C over 47 days, under aerobic conditions 89 percent of eggs developed to the infective stage, whereas under anaerobic conditions eggs did not develop but remained alive (Marti, Booram, and Hale 1980).

Thermophilic digestion, like all other processes involving raised temperatures (>45°C), can be highly effective in *Ascaris* egg destruction (figure 23-2). Burden and Ginnivan (1978) studied seeded *A. suum* eggs in pig slurry (95 percent water) under aerobic thermophilic digestion at 55°C. Ninety percent of unembryonated *A. suum* eggs were dead (judged by failure to embryonate in culture) after 15 minutes, and all were dead after 30 minutes. Embryonated eggs were all dead (judged by failure to infect piglets) after 15 minutes.

By storage

Storage of sludge at ambient temperatures will eliminate *Ascaris* eggs if the storage period is long enough. Nine months were not sufficient in Pretoria, South Africa (Murray 1960), no loss of viability occurred after 44 days in pulverized sludge in the USA (Cram and Hicks 1944), and 2 years were required for complete elimination of *Ascaris* eggs in Moscow, USSR (Vassilkova 1936). *A. suum* eggs stored in silage for up to 4 months were still infective to mice, but eggs stored for 5 months were not (Pavlov 1958).

If storage is accompanied by drying, death will be more rapid, but survival times of several months are still possible. In laboratory experiments in India, sludge samples were kept in open dishes exposed to diffused sunlight. After 51 days, the moisture content had dropped to 3.1 percent, and yet 10 percent of eggs were still viable (Bhaskaran and others 1956).

Survival of *Ascaris* eggs in night soil is more limited than in sludge if the night soil contains urine. Tests in Japan on the viability of *Ascaris* eggs in night soil (1 volume feces to 5 volumes urine) indicated that the minimum storage temperatures and times needed for complete kill were 30°C for 40 days, 32°C for 25 days, or 34°C for 11 days (Nishi 1969).

Storage will be more effective in destroying *Ascaris* eggs in warm or dry climates than in cool or wet climates.

By drying

Desiccation is antagonistic to *Ascaris* eggs. At moisture contents below about 5 percent, death may be fairly rapid, especially at warm temperatures (Keller 1951*a*). These low moisture contents are never achieved in normal sludge drying practice, and a typical "dewatered" sludge contains about 75 percent water. Therefore, sludge drying processes are analogous to sludge storage (see above) in their effects upon *Ascaris* eggs, and long holding times are necessary to eliminate *Ascaris* eggs. Required holding times will be somewhat less in warm climates than in temperate regions.

After 4 years on drying beds at Kharkov (USSR), sludge still contained 18 *Ascaris* eggs per gram near the surface and 7 eggs per gram at a depth of 1 meter (Vishnevskaya 1938). When sludge was dried in the sun in South Africa for 4 months in layers ranging in thickness from 37 to 150 millimeters, *Ascaris* eggs were completely eliminated from the 37-millimeter layer, in which the moisture content had fallen from 84 percent to below 3 percent. *Ascaris* eggs still remained in the thicker layers (Hogg 1950). In other experiments, *Ascaris* survived drying to a point where the moisture content of the sludge reached 5.8 percent but failed to survive when the moisture content reached a lower figure (Cram and Hicks 1944).

By heating

The only method of achieving *Ascaris* egg elimination, without prolonged storage or adding ovicides, is by heating. The literature contains many studies into the time-temperature survival of eggs under different environmental conditions. These studies are sometimes contradictory. All relevant data found in the literature have therefore been plotted on figure 23-2, and an upper boundary line has been drawn. Temperatures and times above this line should guarantee complete destruction of *Ascaris* eggs.

It is clear from figure 23-2 that temperatures of over 45°C must be reached, and preferably over 50°C. The practical way of achieving this is aerobic thermophilic composting of sludge or night soil mixed with organic refuse. Other, somewhat impractical methods have been tried.

In a village in Shiga Prefecture in Japan, a sheet-iron container with a capacity of 14 liters was installed under the seat of each domestic privy (Katayama

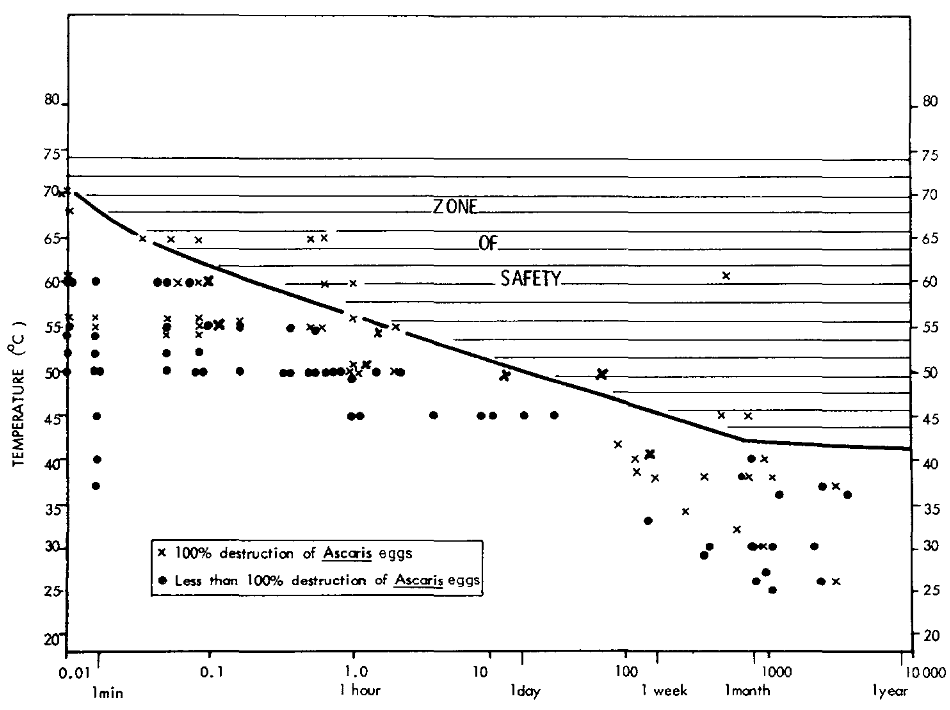

Figure 23-2. *The influence of time and temperature on* Ascaris eggs. The points plotted are the results of experiments done under widely differing conditions. The line drawn represents a conservative upper boundary for death

1955). The contents were emptied occasionally into a 200-liter drum and heated to 60°C with firewood. All parasite eggs and fly maggots were completely destroyed. The night soil was then used for fertilization. The effect was demonstrated by a decline in the prevalence of *Ascaris* and hookworm infections as well as by a decrease in the count of embryonated *Ascaris* eggs found in the farm soil of the village, compared with a nearby control village.

By composting

Aerobic composting of night soil or sludge with refuse, woodchips, straw or other carbonaceous bulking material is an efficient method of eliminating *Ascaris* eggs. Success depends on careful process management and, in particular, on regulation of the moisture content, the carbon to nitrogen ratio, and the pile temperature. It is pile temperature that is crucial to *Ascaris* egg elimination, and the required time-temperature combinations may be read off figure 23-2. To achieve these time-temperature conditions throughout the composting mass requires lagging by covering the heap with old compost or mud, forced draft aeration, regular turning, or a combination of these.

Studies on *Ascaris* eggs in composting processes are listed in table 23-3. *Ascaris* eggs are the most hardy of all excreted pathogens considered in this book. The time-temperature requirements for complete inactivation are more stringent than for other pathogens, with the exception of enteroviruses at short retention times (see figure 9-2). For this reason, and because viruses are technically difficult to enumerate in compost samples, *Ascaris* eggs make an excellent indicator of compost quality. *Ascaris* egg standards for compost have been adopted in China and Vietnam. Where facilities are excellent, a combined enterovirus-*Salmonella*-*Ascaris* standard is appropriate. Where laboratory facilities are more limited, a *Salmonella*-*Ascaris* or fecal streptococci-*Ascaris* standard should be adopted. Where laboratory facilities are poor, an *Ascaris* standard alone will prove adequate.

Table 23-3. *Some studies on* Ascaris *eggs in composting processes*

Country	*Source*
China	Department of Environmental Health (1975) Hou and others (1959) McGarry and Stainforth (1978) Scott (1952. 1953)
Germany Democratic Republic	Borchert and Kalbe (1955) Kalbe (1955)
India	Bhaskaran and others (1957)
Malaysia	Scharff (1940)
Poland	Iwańczuk (1963)
South Africa	Keller (1951*b*, 1951*c*) Krige (1964) Murray (1960) Steer and Windt (1978)
Sri Lanka	Nicholls and Gunawardana (1939)
USA	Brandon (1978) Theis, Bolton and Storm (1978) Wiley and Westerberg (1969)
USSR	Biziulevicius (1961) Gudzhabidze and Lyubchenko (1959)
Reviews of several countries	Feachem and others (1980) Hays (1977) Petrik (1954) Wiley (1962)

By other processes

A variety of more technically complex sludge treatment processes is available. Those that involve heating may be highly effective; those that do not will not. The two exceptions to this are the use of chemical ovicides and irradiation.

CHEMICAL OVICIDES: An alternative to heating is to treat night soil or sludge with an ovicidal chemical. A great variety of chemicals have been tried in the field and in the laboratory. Two field trials in Japan, one of sodium nitrite in acidified night soil and one of thiabendazole, have shown that night soil treatment reduced ascariasis prevalence (Kozai 1960*a*; Kutsumi 1969). The literature on chemical ovicides is listed in table 23-4. A wide variety of chemicals have effect. Sodium nitrite and thiabendazole are the most widely tried. The practicability and cost of this method must be questioned, however. Thermophilic composting of night soil or sludge with refuse is a more realistic, and probably cheaper, method of making fecal products safe for land application. An added advantage of thermophilic composting is that it will destroy all other pathogens in the compost, which has not been claimed for the application of chemical ovicides.

IRRADIATION. Data on the effect of radiation on *Ascaris* eggs in sludge are limited. Brandon (1978) reported that 1.5 kilogray killed over 99 percent of *Ascaris* eggs. Lessel and Suess (1978) found a 100 percent kill at a dose of 3 kilogray, whereas Osborn

Table 23-4. *Some literature on* Ascaris *ovicides*

Ovicide	*Media in which eggs contained*	*Source*
Benzylphenol	Water	Nasiłowska (1963)
Carbathion	Dried sludge	Chilikin (1975)
Carbon disulphide	Cesspool contents	Matsumura and Osawa (1954)
Chlorobenzyl-phenol	Water	Nasiłowska (1963)
Coca Cola	ND	Bacev, Kolev and Peeva (1972)
Creolin	Water	Šimůnek, Krč and Svoboda (1963)
Cresol	Water	Fujita (1959)
	Cesspool contents	Matsumura and Osawa (1954)
Detergents	Water	Jaskoski (1951)
	Vegetables	Kumada (1965*a*; 1965*b*)
Dicapthon (isochloro-thion)	Night soil	Fujita (1960*a*)
	Water	Fujita (1960*b*)
Fertilizers	Water	Hamdy (1969, 1970*b*)
Hexachloro-phenol	Water	Nasiłowska (1963)
Nitric acid	ND	Hsu and Hsu (1940)
p-Thiocresol	Cesspool contents	Matsumura and Osawa (1954)
Pentachloro-phenol	Water	Fujita (1959)
Phenol	ND	Hsu and Hsu (1940)
	Water	Šimůnek, Krč and Svoboda (1963)
	Cesspool contents	Matsumura and Osawa (1954)
Proteins	Night soil	Matsumura and Oda (1954)
Sodium nitrite	Pickle	Kim and Yoon (1966)
	Acidified night soil	Kozai (1960*a*, 1960*b*, 1960*c*, 1962)
	Acidified night soil	Kozai and Kobayashi (1961)
Sodium penta-chloro-phenate	Water, acidified night soil	Kutsumi (1963)
Sulphuric acid	ND	Hsu and Hsu (1940)
Thiabendazole	Pickle	Kim and Yoon (1966)
	Night soil	Kutsumi (1964*a*, 1964*b*, 1969); Kutsumi and Komiya (1965)
Xylene	Cesspool contents	Matsumura and Osawa (1954)

ND No data.

and Hattingh (1978) reported 99 percent inactivation at 1 kilogray but less than 100 percent inactivation at 5 kilogray. It appears that the effect of radiation on *Ascaris* eggs lies somewhere between the effect on bacteria (1 log reduction per 200–300 gray), and the effect on enteroviruses (1 log reduction per 2–5 kilogray).

Literature Cited

Anders, W. (1954). The Berlin sewer workers. *Zeitschrift für Hygiene und Infektionskrankheiten*, **139**, 341–371.

Arfaa, F. and Ghadirian, E. (1978). The effect of mass-treatment in the control of helminthiasis in Isfahan, central Iran. *Iranian Journal of Public Health*, **7**, 100–111.

Arfaa, F., Sahba, G. H., Farahmandian, I. and Jalali, H. (1977). Evaluation of the effect of different methods of control of soil-transmitted helminths in Khuzestan, southwest Iran. *American Journal of Tropical Medicine and Hygiene*, **26**, 230–233.

Atchley, F. O., Wysham, D. N. and Hemphill, E. C. (1956). Mass treatment of ascariasis with a single dose of piperazine citrate. *American Journal of Tropical Medicine and Hygiene*, **5**, 881–887.

Bacev, K., Kolev, G. and Peeva, Z. (1972). Inhibitors of the development of helminth eggs and of rabbit coccidial oocysts. *Epidemiologiia, Microbiologiia i Infektsionzni Bolesti*, **9**, 195–200.

Barchenko, L. I. (1953). The importance of some food products as possible factors in the geohelminth infection of a population. In *Papers on Helminthology Presented to Academician K. I. Skryabin on his 75th Birthday*, pp. 39–43. Moscow: Izdatelstvo Akademii Nauk SSR.

———(1955). Routes of infection with ascariasis in living quarters. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **24**, 122–125.

Baumhogger, W. (1949). Ascariasis in Darmstadt and Hessen as seen by a water-waste engineer. *Zeitschrift für Hygiene und Infektionskrankheiten*, **129**, 488–506.

Ben-Ari, J. (1962). The incidence of *Ascaris lumbricoides* and *Trichuris trichiura* in Jerusalem during the period of 1934–1960. *American Journal of Tropical Medicine and Hygiene*, **11**, 366–368.

Bhaibulaya, M., Punnavutti, V., Yamput, S., Indra-Ngarm, S., Pahuchon, W., Hongsuwan, S., Vajrasthira, S. and Harinasuta, C. (1977). Control trial of soil-transmitted helminthic infections with pyrantel pamoate. *Southeast Asian Journal of Tropical Medicine and Public Health*, **8**, 329–334.

Bhaskaran, T. R., Gosh Roy, B. K., Sampathkumaran, M. A., Radhakrishnan, I. and Mukherjee, D. B. (1957). Studies on the survival of pathogens in nightsoil compost. *Indian Journal of Agricultural Science*, **27**, 91–102.

Bhaskaran, T. R., Sampathkumaran, M. A., Sur, T. C. and Radhakrishnan, I. (1956). Studies on the effect of sewage treatment processes on the survival of intestinal parasites. *Indian Journal of Medical Research*, **44**, 163–180.

Biagi, F. F. and Rodriguez, O. (1960). A study of ascariasis eradication by repeated mass treatment. *American Journal of Tropical Medicine and Hygiene*, **9**, 274–276.

Biziulevicius, S. (1954). Role of vegetables and berries in the epidemiology of helminthiasis in the population of Lithuania. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **23**, 124–126.

———(1965). Studies on the viability of *Ascaris* and *Trichuris* eggs in buried lavatory pits. *Acta Parasitologica Lithuanica*, **5**, 77–84.

———(1961). On the vitality of ascarid (*Ascaris lumbricoides*) and whipworm (*Trichuris trichiura*) eggs in compost manure heaps. *Acta Parasitologica Lithuanica*, **3**, 51–69.

Blumenthal, D. S. (1977). Intestinal nematodes in the United States. *New England Journal of Medicine*, **297**, 1437–1439.

Borchert, A. and Kalbe, I. (1955). Resistance of *Ascaris* eggs in natural compost. *Archiv für experimentelle Veterinärmedizin*, **9**, 142–144.

Bradley, R. M. and Hadidy, S. (1981). Parasitic infestation and the use of untreated sewage for irrigation of vegetables with particular reference to Aleppo, Syria. *Public Health Engineer*, **9**, 154–157.

Brandon, J. R. (1978). *Parasites in Soil/Sludge Systems*. Report SAND77-1970. Albuquerque, N.M.: Sandia Laboratories.

Brown, H. W. (1927). Human *Ascaris* as a household infection. *Journal of Parasitology*, **13**, 206–212.

Bukh, F. L. (1945). The data of helminth egg inspection of the sources of water supply of Ufa. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **14**, 66–67.

Burden, D. J. and Ginnivan, M. J. (1978). The destruction of pig helminth ova and larvae in a slurry treatment process. *Veterinary Record*, **103**, 373–375.

Cabrera, B. D., Arambulo, P. V. III and Portillo, G. P. (1975). Ascariasis control and/or eradication in a rural community in the Philippines. *Southeast Asian Journal of Tropical Medicine and Public Health*, **6**, 510–518.

Chandler, A. C. (1954). A comparison of helminthic and protozoan infections in two Egyptian villages two years after the installation of sanitary improvements in one of them. *American Journal of Tropical Medicine and Hygiene*, **3**, 59–73.

Chen, E. R. and Hsieh, H. C. (1969). Study of ascariasis control in Taiwan. *Journal of the Formosan Medical Association*, **68**, 411–427.

Chen, P. C. (1970). Ascariasis: beliefs and practices of a rural Malay community. *Medical Journal of Malaysia*, **24**, 176–182.

Chilikin, M. M. (1975). The use of carbathion for the anthelminthic treatment of sewage sludge. *Medistinskaia Parazitologiia i Parazitarnye Bolezni*, **44**, 82–86.

Choi, D. W. (1970). Incidence of parasite eggs on vegetable leaves, watercress and carrots. *Korean Journal of Parasitology*, **8**, 19.

Clark, C. S., Cleary, E. J., Schiff, G. M., Linnemann, C. C. Jr, Phair, J. P. and Briggs, T. M. (1976). Disease risks of occupational exposure to sewage. *Journal of the Environmental Engineering Division, American Society of Civil Engineers*, **102**, 375–388.

Cort, W. W. (1931). Recent investigations on the epidemiology of human ascariasis. *Journal of Parasitology*, **17**, 121–144.

Cort, W. W., Otto, G. F. and Spindler, L. A. (1930). Investigations on *Ascaris lumbricoides* and the associated intestinal helminths of man in southwestern Virginia. *American Journal of Hygiene*, **11**, 1–55.

Cort, W. W., Schapiro, L. and Stoll, N. R. (1929). A study of reinfection after treatment with hookworm and *Ascaris* in two villages in Panama. *American Journal of Hygiene*, **10**, 614–625.

Cort, W. W. and Stoll, N. R. (1931). Studies on *Ascaris lumbricoides* and *Trichuris trichiura* in China. *American Journal of Hygiene*, **14**, 655–689.

Cort, W. W., Stoll, N. R., Riley, W. A. and Sweet, W. C. (1929). VIII. Quantitative studies on the distribution of *Ascaris lumbricoides* and *Trichuris trichiura* in Panama. *American Journal of Hygiene Monographic Series No. 9*, 161–209.

Coumbaras, A., Larivière, M., Beauvais, B., Languillat, G. and Turquet, M. (1976). Le charge parasitaire moyenne, critère d'évaluation de la contamination géohelminthique d'une population, et d'application des actions d'assainissement. *Bulletin de la Société de Pathologie Exotique et de ses Filiales*, **69**, 95–100.

Cram, E. B. (1943). The effect of various treatment processes on the survival of helminth ova and protozoan cysts in sewage. *Sewage Works Journal*, **15**, 1119–1138.

Cram, E. B. and Hicks, D. O. (1944). The effect of sludge digestion, drying and supplemental treatment on eggs of *Ascaris lumbricoides*. *Proceedings of the Helminthological Society of Washington*, **11**, 1–9.

Department of Environmental Health, Institute of Health, Chinese Academy of Medical Sciences, Peking (1975). Sanitary effects of urban garbage and nightsoil composting. *Chinese Medical Journal*, **1**, 407–412.

Drozdova, Z. K., Romanenko, N. A., Lapshina, I. G., Andreeva, N. L., Vlasova, N. I. and Guseva, M. K. (1973). The survival rate of *Ascaris* eggs in the soil and sludge in a silty area of the Volgograd region. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **42**, 146–148.

Dunlop, S. C. and Wang, W. L. L. (1961). Studies on the use of sewage effluent for irrigation of truck crops. *Journal of Milk and Food Technology*, **23**, 44–47.

Eyles, D. E., Jones, F. E. and Smith, C. S. (1953). A study of *Endamoeba histolytica* and other intestinal parasites in a rural West Tennessee community. *American Journal of Tropical Medicine and Hygiene*, **2**, 173–190.

Faust, E. C. and Mugaburu, L. G. (1965). Parasitological surveys in Cali, Departamento del Valle, Colombia. XI. Intestinal parasites in Ward Siloé, Cali, during a four-year period 1956–1960. *American Journal of Tropical Medicine and Hygiene*, **14**, 276–289.

Feachem, R. G., Bradley, D. J., Garelick, H. and Mara, D. D. (1980). *Health Aspects of Excreta and Sullage Management: A State-of-the-Art Review*. Appropriate Technology for Water Supply and Sanitation, vol. 3. Washington, D.C.: The World Bank, Transportation, Water and Telecommunications Department.

Fitzgerald, P. R. (1981). *Helminth and Heavy Metals*

Transmission from Anaerobically Digested Sewage Sludge. Report EPA-600/S2-81-024. Cincinnatti, Ohio: US Environmental Protection Agency.

Fitzgerald, P. R. and Ashley, R. F. (1977). Differential survival of *Ascaris* ova in wastewater sludge. *Journal of the Water Pollution Control Federation*, **49**, 1722–1724.

Forstner, M. J. (1960). Parasitological investigations in the sewage works of Mindelheim to answer the question of worm infection of pasturing cattle on pastures watered with waste water. *Berliner und Münchener tierarztliche Wochenschrift*, **73**, 161–164.

Freij, L., Meeuwisse, G. W., Berg, N. O., Wall, S. and Gebre-Medhin, M. (1979). Ascariasis and malnutrition. A study in urban Ethiopian children. *American Journal of Clinical Nutrition*, **32**, 1545–1553.

Fujita, K. (1959). Studies on the ovicidal effects of various agricultural chemicals on *Ascaris* eggs. 1. Experiments *in vitro*. *Japanese Journal of Parasitology*, **8**, 580–585.

——— (1960*a*). Studies on the ovicidal effects of agricultural chemicals on *Ascaris* eggs. 2. Effects on the eggs in nightsoil. *Japanese Journal of Parasitology*, **9**, 69–72.

——— (1960*b*). Studies on the ovicidal effects of agricultural chemicals on *Ascaris* eggs. 3. Influence of temperatures upon the effectiveness. *Japanese Journal of Parasitology*, **9**, 125–128.

Fulmer, H. S. and Huempfner, H. R. (1965). Intestinal helminths in eastern Kentucky: a survey in three rural counties. *American Journal of Tropical Medicine and Hygiene*, **14**, 269–275.

Garcia, E. G., Cabrera, B. D., Cruz, T. A. and Jueco, N. L. (1961). Reinfection rates of successfully treated cases of ascariasis. *Journal of the Philippine Medical Association*, **37**, 239–243.

Gärtner, H. and Müting, L. (1951*a*). On the infiltration depth of *Ascaris* eggs in land. *Zeitschrift für Hygiene und Infektionskrankheiten*, **132**, 59–63.

——— (1951*b*). Survival of *Ascaris* eggs in land irrigated with sewage. *Zeitschrift für Hygiene und Infektionskrankheiten*, **132**, 244–249.

Gelpi, A. P. and Mustafa, A. (1967). Seasonal pneumonitis with eosinophilia: a study of larval ascariasis in Saudi Arabs. *American Journal of Tropical Medicine and Hygiene*, **16**, 646–657.

Ghadirian, E., Arfaa, F., Missaghian, Gh. and Bahrani, H. (1973). Prevalence of intestinal helminthiasis in Kermanshah city and some villages in the province. *Iranian Journal of Public Health*, **2**, 90–101.

Goryachev, P. P. (1947). Investigation of helminth eggs in the waters of the rivers Irtish and Om. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **16**, 75–78.

Gudzhabidze, S. I. and Lyubchenko, S. D. (1959). Control of ascariasis and ancylostomiasis by composting of organic waste material. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **28**, 576–578.

Gupta, M. C., Mithal, S., Arora, K. L. and Tandon, B. N. (1977). Effect of periodic deworming on nutritional status of *Ascaris*-infested preschool children receiving supplementary food. *Lancet*, **2**, 108–110.

Hamdy, E. I. (1969). Effect of some nitrogenous fertilizers on *Ascaris lumbricoides* eggs. *Journal of the Egyptian Medical Association*, **52**, 949–953.

——— (1970*a*). Urine as an *Ascaris lumbricoides* ovicide. *Journal of the Egyptian Medical Association*, **53**, 261–264.

——— (1970*b*). On the value of some non-nitrogenous fertilizers as *Ascaris* ovicides. *Journal of the Egyptian Medical Association*, **53**, 363–367.

Hays, B. D. (1977). Review paper: Potential for parasitic disease transmission with land application of sewage plant effluents and sludges. *Water Research*, **11**, 583–595.

Hendley, J. O., Williams, D. and Burke, G. (1973). Familial carriage of *Ascaris*. *Pediatric Research*, **7**, 375/147.

Hogg, E. S. (1950). A preliminary study of ova and cysts in Cydna digested sludge. *Journal of the Institute of Sewage Purification*, part 1, 57–58.

Hoghooghi, N., Badami, N., Barnett, R. and Jalayer, T. (1973). A survey of soil contamination and viability of *Ascaris lumbricoides* eggs in Isfahan, Iran. *Pahlavi Medical Journal*, **4**, 53–60.

Hou, T. C., Chung, H. L., Ho, L. Y. and Weng, H. C. (1959). Achievements in the fight against parasitic diseases in New China. *Chinese Medical Journal*, **79**, 493–520.

Hsu, Y. C. and Hsu, H. S. (1940). Effects of chemical reagents on the development of eggs of *Ascaris lumbricoides*. *Peking Natural History Bulletin*, **15**, 103–118.

Iwańczuk, I. (1963). Influence of compost making on the eggs of man human intestinal helminths. *Przeglad Epidemiologiczny*, **17**, 327–335.

——— (1969). Exploration of river shores for the presence of human intestinal parasites. *Wiadomości Parazytologiczne*, **15**, 67–70.

Iwańczuk, I. and Dożańska, W. (1957). The influence of chlorination on the survival of *Ascaris suis* eggs in sewage. *Acta Parasitologica Polonica*, **5**, 429–448.

Jancloes, M. F., Cornet, P. and Thienpont, D. (1979). Mass control of ascariasis with single oral doses of levamisole: a controlled comparison in 3,056 subjects between three incomplete population coverages. *Tropical and Geographical Medicine*, **31**, 111–121.

Jaskoski, B. J. (1951). Effects of detergents on embryogeny of *Ascaris lumbricoides* var. *suum*. *Journal of Parasitology*, **37**, 22.

Jones, H. I. (1976*a*). The role of pigs in the dissemination of *Ascaris* and hookworm infections in Papua New Guinea. *Papua New Guinea Medical Journal*, **19**, 153–155.

——— (1976*b*). A study of human intestinal helminthiases on Kar Kar Island, Madang Province. *Papua New Guinea Medical Journal*, **19**, 165–172.

Jueco, N. L. and Cabrera, B. D. (1971). Reinfection rates of successfully treated cases of ascariasis in Victoria, Laguna. *Journal of the Philippine Medical Association*, **47**, 449–454.

Kabler, P. (1959). The removal of pathogenic micro-organisms by sewage treatment processes. *Sewage and Industrial Wastes*, **31**, 1373–1382.

Kalbe, I. (1955). The action of natural composting on the viability of *Ascaris* ova. *Deutsche Landwirtschaft*, **6**, 440–441.

——(1956). Investigations of parasites in sewage in several towns in East Germany. *Zeitschrift für die Gesamte Hygiene und ihre Grenzgebiete*, **2**, 334–343.

Katayama, Y. (1955). Sanitary treatment of human excreta by heating process. 16. Effect of the treatment applied to a farm-village. Part 1. *Japanese Journal of the Nation's Health*, **24**, 1–12.

Kawagoe, K., Nishi, H., Shibata, E. and Yamada, S. (1958). On the effect of nightsoil treatment upon heating process utilizing surplus midnight electric power upon the incidence of parasitic infection of farmers. *Japanese Journal of the Nation's Health*, **27**, 162–165.

Keller, P. (1951*a*). Sterilization of sewage sludges. 1. A review of the literature pertaining to the occurrence and viability of parasitic ova and cysts in sewage with particular reference to *Ascaris lumbricoides*. *Journal of the Institute of Sewage Purification*, part 1, 92–99.

——(1951*b*). Sterilization of sewage sludges. 2. The influence of heat treatment on the ova of *Ascaris lumbricoides* in sewage. *Journal of the Institute of Sewage Purification*, part 1, 100–109.

——(1951*c*). Sterilization of sewage sludges. *Public Health*, Johannesburg, **15**, 11–17.

Keller, P. and Hide, C. G. (1951). Sterilization of sewage sludges. Incidence and relative viability of *Ascaris* ova at sewage disposal works in the Johannesburg area. *South African Medical Journal*, **25**, 338–342.

Khalil, M. (1926). The relation between sanitation and parasitic infections in the tropics. *Journal of the Royal Sanitary Institute*, **47**, 210–215.

——(1931). The pail closet as an efficient means of controlling human helminth infection as observed in Tura Prison, Egypt, with a discussion on the source of *Ascaris* infection. *Annals of Tropical Medicine and Parasitology*, **25**, 35–62.

——(1933). *Report on the Mission of the Research Institute, Public Health Department, and the Faculty of Medicine, Cairo, to Siwa Oasis, in January 1933, for the Study of Parasitic Infections, Malaria and Diphtheria.* Cairo: Ministry of the Interior, Public Health Department.

Khaustov, J. M. (1935). Vegetables as a factor in transmission of *Trichocephalus* (*Trichuris*) *trichiuris*. *Trudy Leningradskogo Instituta Epidemiologii i Bakteriologii imeni Pastera*, **2**, 148–152.

Kim, C. H. and Yoon, T. Y. (1966). Action of several chemicals on parasite eggs and larvae in Korean pickle (kimchi). *Korean Journal of Parasitology*, **4**, 47–51.

Kirpichnikov, A. A. (1963). Methods of treating town refuse. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **32**, 147–151.

Kleevens, J. W. L. (1966). Re-housing and infections by soil-transmitted helminths in Singapore. *Singapore Medical Journal*, **7**, 12–29.

Koltypin, Y. A. (1969). Decontamination of sewage in paddy fields. *Gigiena i Sanitaria*, No. 7, 74–76.

Kozai, I. (1960*a*). Re-evaluation of sodium nitrite as an ovicide for nightsoil. (1). *Japanese Journal of Parasitology*, **9**, 202–210.

——(1960*b*). Re-evaluation of sodium nitrite as an ovicide for night soil. (2). *Japanese Journal of Parasitology*, **9**, 519–528.

——(1960*c*). Re-evaluation of sodium nitrite as an ovicide for night soil. (3). *Japanese Journal of Parasitology*, **9**, 529–540.

——(1962). Re-evaluation of sodium nitrite as an ovicide for night soil. (4). *Japanese Journal of Parasitology*, **11**, 400–410.

Kozai, I. and Kobayashi, A. (1961). Ovicidal effect of a sodium nitrite preparation 'Derisan' on *Ascaris* ova in nightsoil. *Japanese Journal of Parasitology*, **10**, 56–61.

Králová, E. and Šafránek, V. (1957). Helminthological investigation of sediments from the waste water refining station at Kouřim. *Československá Hygiena*, **2**, 399–404.

Krige, P. R. (1964). A survey of the pathogenic organisms and helminthic ova in composts and sewage sludge. *Journal of the Institute of Sewage Purification*, part 3, 215–220.

Krishnaswami, M. A. and Post, F. J. (1968). Effect of chlorine on *Ascaris* (Nematoda) eggs. *Health Laboratory Science*, **5**, 225–232.

Kumada, M. (1965*a*). Tests of synthetic detergents on sale for their potency in eliminating *Ascaris* eggs on vegetable leaves, with special reference to fat removal test. *Japanese Journal of Parasitology*, **14**, 162–168.

——(1965*b*). Some factors influencing the action of detergent in eliminating *Ascaris* eggs from vegetable leaves. *Japanese Journal of Parasitology*, **14**, 495–499.

Kutsumi, H. (1963). Studies on ovicides against helminth eggs *in vitro*. I. Ovicidal activity of NaPCP on *Ascaris* eggs and its decomposition by ultra-violet irradiation. *Japanese Journal of Parasitology*, **12**, 485–496.

——(1964*a*). Studies on ovicides against helminth eggs *in vitro*. II. The ovicidal activity of thiabendazole against *Ascaris* eggs in water and in nightsoil. *Japanese Journal of Parasitology*, **13**, 32–42.

——(1964*b*). Studies on ovicides against helminth eggs *in vitro*. III. Ovicidal effects of water-soluble and semi-water-soluble thiabendazole on *Ascaris* eggs in nightsoil and the time-concentration relationship for complete inhibition of larval formation. *Japanese Journal of Parasitology*, **13**, 123–131.

——(1969). Epidemiological study on the preventive effect of thiabendazole as an ovicide against human hookworm. *Trichuris* and *Ascaris* infections. *Japanese Journal of Medical Science and Biology*, **22**, 51–64.

Kutsumi, H. and Komiya, Y. (1965). Effect of thiabendazole as an ovicide on helminth eggs in nightsoil. *Japanese Journal of Medical Science and Biology*, **18**, 203–224.

Lakshminarayana, J. S. S. and Abdulappa, M. K. (1969). The effect of sewage stabilization ponds on helminths. In *Low Cost Waste Treatment*, ed. Sastry, C. A., pp. 290–299. Nagpur, India: Central Public Health Engineering Research Institute.

Lane, C. (1934). The prevention of *Ascaris* infection: a critical review. *Tropical Diseases Bulletin*, **31**, 605–615.

Lessel, T. and Suess, A. (1978). Hygienization of sewage sludge by gamma irradiation: experience with an operating pilot plant. *Progress in Water Technology*, **10**, 641–652.

Liebmann, H. (1965). Investigations about helminth ova in sewage and wastes in Japan. *Berliner und Munchener Tierarztliche Wochenschrift* **78**, 106–108.

Livingstone, D. J. (1978). Decay of microorganisms in the marine environment. In *Proceedings of the Symposium on Disinfection of Water*. Pretoria, South Africa: National Institute for Water Research.

Lo, E. K. C., Varughese, J., Ghouse, A. and Noor, M. (1979). Helminthiases in peninsular Malaysia—prevalence and density of infestation of hookworm, *Ascaris* and *Trichuris* in rural school children. *Medical Journal of Malaysia*, **34**, 95–99.

Lýsek, H. (1959). A contribution to the role of soil and vegetables in the epidemiology of geohelminths. *Československá Epidemiologie, Mikrobiologie, Imunologie*, **8**, 137–140.

———(1964). On the destruction of *Ascaris* eggs in the soil. In *Proceedings of the First International Congress of Parasitology, Rome, Sept. 21–26, 1964*, vol. 2, pp. 788–789. Oxford: Pergamon.

Lýsek, H. and Bačovský, J. (1979). Penetration of ovicidal fungi into altered eggs of *Ascaris lumbricoides*. *Folia Parasitologica*, **26**, 139–142.

McGarry, M. G. and Stainforth, J. (1978). *Compost, Fertilizer and Biogas Production from Human and Farm Wastes in the People's Republic of China*. Ottawa: International Development Research Centre.

Marti, O. G., Booram, C. V. and Hale, O. M. (1980). Survival of eggs and larvae of swine nematode parasites in aerobic and anaerobic waste treatment systems. *Journal of Environmental Quality*, **9**, 401–405.

Massoud, J. (1980). Long-term mass-chemotherapy in reducing some common soil-transmitted helminths infection in Khuzestan, South-West of Iran. Abstract no. 232. *Abstracts of the 10th International Congress on Tropical Medicine and Malaria*. Manila, Philippines.

Massoud, J., Arfaa, F., Jalali, H. and Keyvan, S. (1980). Prevalence of intestinal helminths in Khuzestan, southwest Iran, 1977. *American Journal of Tropical Medicine and Hygiene*, **29**, 389–392.

Mata, L. J., Kromal, R. A., Urrutia, J. J. and Garcia, B. (1977). Effect of infection on food intake and the nutritional state: perspectives as viewed from the village. *American Journal of Clinical Nutrition*, **30**, 1215–1227.

Matsumura, T. and Oda, T. (1954). Studies on increase of death of *Ascaris* eggs in the mixture of feces and urine on protein addition. *Gunma Journal of Medical Sciences*, **3**, 233–234.

Matsumura, T. and Osawa, M. (1954). Experimental studies on *Ascaris* prevention by chemical disposal of cesspool. *Gunma Journal of Medical Sciences*, **3**, 319–320.

Mobedi, I., Arfaa, F. and Movafegh, C. (1971). Studies on intestinal helminthiasis in Dickleh, Arasbaran, northwest Iran. *Acta Medica Iranica*, **14**, 153–157.

Moore, H. A., de la Cruz, E. and Vargas-Mendez, O. (1965). Diarrheal disease studies in Costa Rica. IV. The influence of sanitation upon the prevalence of intestinal infection and diarrheal disease. *American Journal of Epidemiology*, **82**, 162–184.

Murray, H. M. (1960). The incidence of *Ascaris* ova in Pretoria sludge and their reduction by storage (maturation) in large heaps. *Journal of the Institute of Sewage Purification*, parts 3–4, 337–344.

Nasiłowska, M. (1963). The action of N-methylditiocarbamic acid and preparations based on diphenylomethanes on eggs of helminths. *Wiadomości Parazytologiczne*, **9**, 139–141.

Nicholls, L. and Gunawardana, S. A. (1939). The destruction of helminth ova in nightsoil by composting. *Ceylon Journal of Science*, Section D, **5**, 1–9.

Nishi, S. (1969). Studies on the ovicidal effect of nightsoil on *Ascaris* eggs. *Japanese Journal of Parasitology*, **18**, 131–140.

Nolf, L. O. (1932). Experimental studies on certain factors influencing the development and viability of the ova of the human *Trichuris* as compared with those of the human *Ascaris*. *American Journal of Hygiene*, **16**, 288–322.

Nupen, E. M. and de Villiers, R. H. (1975). *The Evaluation of Pathogenic Parasites in Water Environments*. Project Report no. 13. Pretoria, South Africa: National Institute for Water Research.

Osborn, D. W. and Hattingh, W. H. J. (1978). Disinfection of sewage sludge: a review. *Water South Africa*, **4**, 169–178.

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.

Otto, G. F. and Spindler, L. A. (1930). Effect of partial sanitation on infestation with intestinal parasites in southwest Virginia. *Southern Medical Journal*, **23**, 556–561.

Panicker, P. V. R. C. and Krishnamoorthi, K. P. (1978). Elimination of enteric parasites during sewage treatment processes. *Indian Association for Water Pollution Control Technical Annual*, **5**, 130–138.

Pavlov, P. (1958). Research on the action of ensilage on nematode eggs and larvae during storage. *Československá Parasitologie*, **5**, 125–128.

Petrik, M. (1954). Utilization of nightsoil, sewage, and sewage sludge in agriculture. *Bulletin of the World Health Organization*, **10**, 207–228.

Pierce, V., Ascoli, W., de Leon, R. and Gordon, J. E. (1962). Studies of diarrheal disease in Central America. III. Specific etiology of endemic diarrhea and dysentery in Guatemalan children. *American Journal of Tropical Medicine and Hygiene*, **11**, 395–400.

Ptitsyna, E. I. (1966). Dehelminthization of sewage in biological oxidation ponds. *Gigiena i Sanitaria*, no. 5, 105–107.

Raccurt, C., Vial, P. and Pierre-Louis, J. M. (1977). Étude épidémiologique des helminthiases intestinales a l'île de la Tortue (Haiti). *Bulletin de la Société de Pathologie Exotique et de ses Filiales*, **70**, 240–249.

Reyes, W. L., Krusé, C. W. and Batson, M. St. C. (1963). The effect of aerobic and anaerobic digestion on eggs of *Ascaris lumbricoides* var. *suum* in nightsoil. *American Journal of Tropical Medicine and Hygiene*, **12**, 46–55.

Romanenko, N. A. (1969). Sanitary-helminthic evaluation of subterranean irrigation with untreated sewage. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **38**, 154–156.

———(1971). Sanitary-helminthological evaluation of new methods of irrigation with sewage. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **40**, 361–362.

Rosenberg, A. I. (1960). Sanitary and hygienic measures for the control of focal ascariasis. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **29**, 143–149.

Rowan, W. B. (1964). Sewage treatment and schistosome eggs. *American Journal of Tropical Medicine and Hygiene*, **13**, 572–576.

Rowan, W. B. and Gram, A. L. (1959). Quantitative recovery of helminth eggs from relatively large samples of feces and sewage. *Journal of Parasitology*, **45**, 615–621.

Rudolfs, W., Falk, L. L. and Ragotzkie, R. A. (1950). Literature review on the occurrence and survival of enteric, pathogenic, and related organisms in soil, water, sewage and sludges, and on vegetation. II. Animal parasites. *Sewage and Industrial Wastes*, **22**, 1417–1427.

———(1951*a*). Contamination of vegetables grown in polluted soil. III. Field studies on *Ascaris* eggs. *Sewage and Industrial Wastes*, **23**, 656–660.

———(1951*b*). Contamination of vegetables grown in polluted soil. V. Helminthic decontamination. *Sewage and Industrial Wastes*, **23**, 853–860.

———(1951*c*). Contamination of vegetables grown in polluted soil. VI. Applications of results. *Sewage and Industrial Wastes*, **23**, 992–1000.

Sadighian, A., Arfaa, F., Ghadirian, E. and Movafagh, K. (1976). Contamination with helminth eggs of various processing stages of the sewage treatment plant in Isfahan, Central Iran. *Iranian Journal of Public Health*, **5**, 180–187.

Sahba, G. H. and Arfaa, F. (1967). The effect of sanitation on ascariasis in an Iranian village. *Journal of Tropical Medicine and Hygiene*, **70**, 37–39.

Scharff, J. W. (1940). Composting: the safe conversion of village refuse and nightsoil into a valuable manure. *Journal of the Malaya Branch, British Medical Association*, **4**, 126–135.

Schliessmann, D. J., Atchley, F. O., Wilcomb, M. J. and Welch, S. F. (1958). *Relation of Environmental Factors to the Occurrence of Enteric Diseases in Areas of Eastern Kentucky*. Public Health Monograph no. 54. Washington, D.C.: US Government Printing Office.

Scott, J. A. and Barlow, C. H. (1938). Limitations to the control of helminth parasites in Egypt by means of treatment and sanitation. *American Journal of Hygiene*, **27**, 619–648.

Scott, J. C. (1952). *Health and Agriculture in China: a Fundamental Approach to Some of the Problems of World Hunger*. London: Faber and Faber.

———(1953). Health aspects of composting with nightsoil. Unpublished document, WHO/Env./San./44. Geneva: World Health Organization.

Seo, B. S., Cho, S. Y. and Chai, J. Y. (1979). Seasonal fluctuation of *Ascaris* reinfection incidences in a rural Korean population. *Korean Journal of Parasitology*, **17**, 11–18.

Seo, B. S., Rim, H. J., Loh, I. K., Lee, S. H., Cho, S. Y., Park, S. C., Bae, J. W., Kim, J. H., Lee, J. S., Koo, B. Y. and Kim, K. S. (1969). Study on the status of helminthic infections in Koreans. *Korean Journal of Parasitology*, **7**, 53–70.

Šimúnek, J., Krč, M. and Svoboda, L. (1963). A contribution on the action of ovicides on *Ascaris suis* in clean and polluted environments. *Československá Parasitologie*, **10**, 277–281.

Sinnecker, H. (1958). The epidemiological significance of urban sewage in the spread of possible zooparasitic infections. *Zeitschrift für die Gesamte Hygiene und ihre Grenzgebiete*, **4**, 98–115.

Soh, C. T. (1960). The effects of natural food-preservative substances on the development and survival of intestinal helminth eggs and larvae. I. Action on *Ascaris lumbricoides* eggs. *American Journal of Tropical Medicine and Hygiene*, **9**, 1–7.

———(1973). Control of soil-transmitted helminths in Korea. *Yonsei Reports on Tropical Medicine*, **4**, 102–125.

Soh, C. T., Kim, S. J., Chang, B. P., Youn, B. B. and Lee, J. H. (1973). Faecal pollution in relation to soil-transmitted helminthic infections. *Korean Journal of Parasitology*, **11**, 133.

Spillmann, R. K. (1975). Pulmonary ascariasis in tropical communities. *American Journal of Tropical Medicine and Hygiene*, **24**, 791–800.

Spindler, L. A. (1929). The relation of moisture to the distribution of human *Trichuris* and *Ascaris*. *American Journal of Hygiene*, **10**, 476–496.

Steer, A. G. and Windt, C. N. (1978). Composting and the fate of *Ascaris lumbricoides* ova. *Water South Africa*, **4**, 129–133.

Stephenson, L. S. (1980). The contribution of *Ascaris lumbricoides* to malnutrition in children. *Parasitology*, **81**, 221–233.

Stephenson, L. S., Crompton, D. W. T., Latham, M. C., Schulpen, T. W. J., Nesheim, M. C. and Jansen, A. A. J. (1980). Relationships between *Ascaris* infection and growth of malnourished preschool children in Kenya. *American Journal of Clinical Nutrition*, **33**, 1165–1172.

Stiles, C. W. and Crohurst, H. R. (1923). The principles underlying the movement of *Bacillus coli* in groundwater, with resulting pollution of wells. *Public Health Reports*, **38**, 1350–1353.

Szechwan Research Institute of Antiparasitic Diseases and Mienchu County Antischistosomiases Office, Szechwan (1974). Digestion of nightsoil for destruction of parasite ova. A report of investigation and experimental observation. *Chinese Medical Journal*, **93**, 31.

Takenouchi, H., Kataoka, I., Yamamoto, S. and Nagasaki, S. (1980). Detection of parasite eggs in surplus sludges from night soil disposal plants. 1. Distribution survey of parasite eggs in Kochi Prefecture. *Japanese Journal of Parasitology*, **29**, 319–324.

Theis, J. H., Bolton, V. and Storm, D. R. (1978). Helminth ova in soil and sludge from twelve U.S. urban areas. *Journal of the Water Pollution Control Federation*, **50**, 2485–2493.

Thiers, G., Lassoued, H. and Abid, A. (1976). Study of ascariasis in a single locality of the Cap Bon region (Tunisia). *Bulletin de la Société Pathologie Exotique et de ses Filiales*, **69**, 320–329.

Thitasut, P. (1961). Action of aqueous solutions of iodine on fresh vegetables and on the infective stages of some common intestinal nematodes. *American Journal of Tropical Medicine and Hygiene*, **10**, 39–43.

Tomomatsu, S. and Takeuchi, M. (1961). Studies on prevention of *Ascaris* infection by soaking raw vegetables in iodine–potassium iodide solution. *Japanese Journal of Parasitology*, **10**, 527–530.

UNEP (1976). *Report on UNEP Schistosomiasis Study Tour of China from 31 October to 18 November 1975.* Unpublished/mimeographed. Nairobi: United Nations Environment Programme.

Usacheva, A. M. (1951). Survival of helminth eggs in water and in river sediment. *Gigiena i Sanitaria*, Part 2, no. 12, 12–17.

van Zijl, W. J. (1966). Studies on diarrhoeal diseases in seven countries by the WHO Diarrhoeal Diseases Advisory Team. *Bulletin of the World Health Organization*, **35**, 249–261.

Vassilkova, Z. (1936). On the dehelminthization of purified sewage by intensive methods. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **5**, 671–674.

———(1940). Viability of helminth eggs in pit latrines. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **9**, 231–237.

———(1941). Evaluation of the contamination of vegetables with eggs of helminths in sewage farms with different methods of cultivation. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **10**, 217–225.

———(1950). Infestation of vegetables with helminth eggs by irrigation with purified sewage water. *Gigiena i Sanitaria*, No. 6, 41–43.

Vishnevskaya, S. M. (1938). The degree of dehelminthization of sewage at the Kharkov bio-station. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **7**, 450–454.

Wang, W. L. L. and Dunlop, S. G. (1954). Animal parasites in sewage and irrigation water. *Sewage and Industrial Wastes*, **26**, 1020–1032.

Warren, K. S. (1974). Helminthic diseases endemic in the United States. *American Journal of Tropical Medicine and Hygiene*, **23**, 723–730.

Wiley, B. B. and Westerberg, S. C. (1969). Survival of human pathogens in composted sewage. *Applied Microbiology*, **18**, 994–1001.

Wiley, J. S. (1962). Pathogen survival in composting municipal wastes. *Journal of the Water Pollution Control Federation*, **34**, 80–90.

Willett, W. C., Kilama, W. L. and Kihamia, C. M. (1979). *Ascaris* and growth rates: a randomized trial of treatment. *American Journal of Public Health*, **69**, 987–991.

Winfield, G. F. (1937). Studies on the control of fecal-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.

Winfield, G. F. and Yao, T. (1937). Studies on the control of fecal-borne diseases in North China. IV. Vegetables as a factor in the spread of *Ascaris lumbricoides*. *Chinese Medical Journal*, **51**, 919–926.

Wright, W. H., Cram, E. B. and Nolan, M. O. (1942). Preliminary observations on the effect of sewage treatment processes on the ova and cysts of intestinal parasites. *Sewage Works Journal*, **14**, 1274–1280.

Yan, C. W., Ishak, F., Hee, G. L., Devaraj, J. M., Ismail, K., Jalleh, R. P., Peng, T. L. and Jalil, T. M. A. (1978). The problem of soil transmitted helminths in squatter areas around Kuala Lumpur. *Medical Journal of Malaysia*, **33**, 34–43.

Yarulin, G. R. (1955). Contamination of the coastal zone of the Caspian Sea with eggs of geohelminths. *Meditsinskaia Parazitologiia i Parazitarnye Bolezni*, **24**, 117–120.

Zaman, V. and Visuvalingam, N. (1967). Action of aqueous iodine on ova of *Ascaris lumbricoides* and *Ascaris suum*. [Correspondence.] *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **61**, 443–444.