# "Helminths and Sanitation"

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Helminths are worms causing a wide variety of diseases globally called helminthiases. Helminthiases almost only occur in developing countries, particularly in areas where sanitation is low sanitation. Although helminths are not microscopic animals, their eggs, which are the infective agents, are. Helminth eggs are discharged to the environment in faeces and the oral-faecal route is the main dissemination pathway of the disease. The inadequate management and disposal of wastewater, sludge and faecal sludge[1] pollutes crops, water and food that when ingested serve as vehicles for transmiting the disease. Unfortunately, there is a lack of knowledge about the sanitary control of helminths in specialized literature. This chapter reviews current and recent information concerning pathogenic helminths, the characteristics of their eggs and sanitary strategies controling them.

**Keywords:** helminth ova; pathogens; sludge; treatment; wastewater reuse

## 1. General characteristics

### 1.1 Classification

There are three different kinds of helminths (Figure 1): (a) Plathelminths or flat worms, (b) Nemathelminths (Aschelminths) or non-segmented round worms, and (c) Annelida or segmented round worms. Those infecting humans through wastewater, sludge or faecal sludge belong only to the first two groups. Helminths are pluri-cellular worms with sizes varying from 1 mm to several m in length; thus, they are not microbes although their eggs are microscopic.

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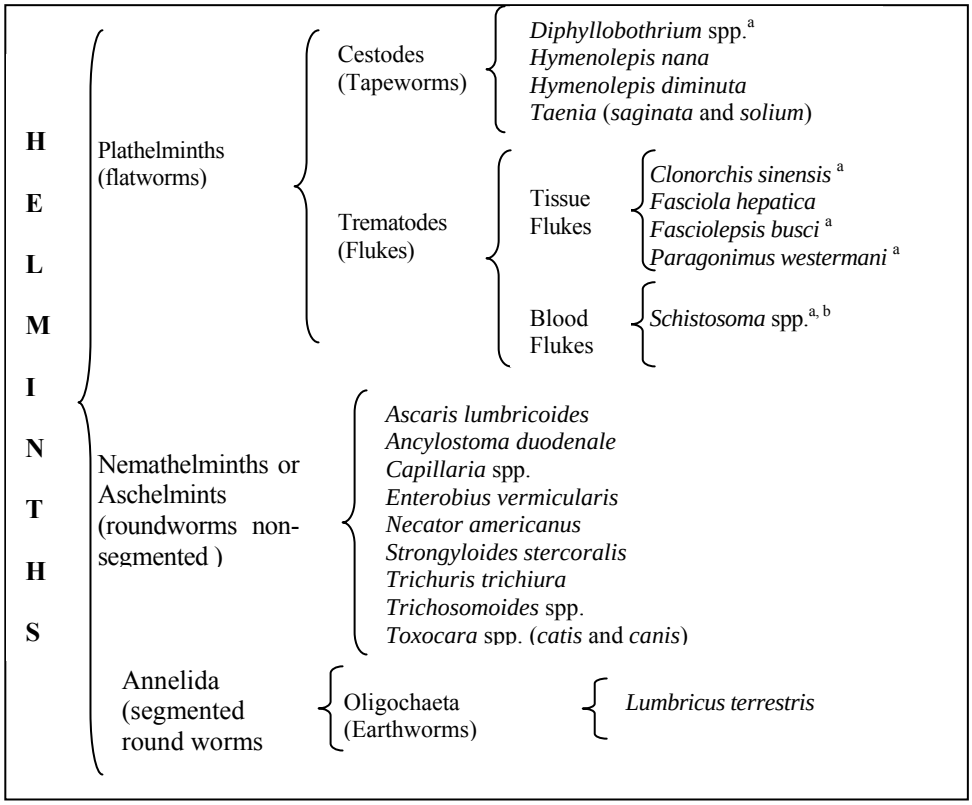
[1] Sludge is the product formed during wastewater treatment in plants while faecal sludge refers to the material accumulated in latrines or other kinds of individual sanitation systems.




[a] Reported in wastewater or sludge from some countries in Asia.
[b] Reported in wastewater or sludge from North Africa and Far East [1]
**Fig. 1** Helminth classification and common genera found in wastewater and sludge.

### 1.2 Helminths' life cycle

Helminths have different and complex life cycles and ideal living environments. Helminths' life cycle is very different from that of bacteria and protozoan, which are well-known microbes in the sanitary field.

The *Ascaris lumbricoide's* life cycle illustrates these differences well. Wastewater or sludge containing *Ascaris* eggs and used for agricultural works pollute crops. These eggs are not normally infective and to become so they need to develop a larva (embryonated egg). The larva develops in the normal temperature and moisture of soil and crops in around 10 days. If a person ingests 1 to 10 *Ascaris* eggs, by consuming polluted crops for instance, the eggs travel to the intestine adhering to the duodenum. There, the larva begins to develop producing an enzyme that dissolves the shell. When the eggs hatch, the larva leaves the egg, crosses the intestine wall and enters the blood stream. Through the blood *Ascaris* is transported to the heart, lungs and bronchus tubes. The larva remains in the lungs for approximately 10 days before travelling to the trachea from where it is ingested and returned once again to the intestine. During its journey, many larvae are destroyed, as they are lost in tissues unsuited to their development, but in other cases the larva forms cysts (in the kidneys, bladder, appendix, pancreas or liver) producing damage and requiring surgical removal [2]. Back in the intestine, 2-3 months after its departure, *Ascaris* reaches its adult phase, and, if female, produces up to 27 million eggs. Eggs are passed to the faeces in the unembryonated state and the life cycle begins once again.

Other helminths have an intermediate host, like *Schistosoma* spp. Schistosoma causes schistosomiasis, a common disease in 54 African and some Asian countries. Schistosoma belong to the Trematode group and those infecting humans are colloquially known as blood flukes. During their life cycle schistosomas mature eggs are discharged with faeces into the water. The eggs hatch in response to

the temperature and light to release the small free swimming larva miracidia. The miracidia penetrate different classes of fresh snails that serve as intermediate host. In around 4 weeks the miracidia develop via a complex sporocyst scheme to the larva cercarial stage forming a single miracidium and thousands of cercariae are produced. The cercariae are once again excreted to water bodies, infecting humans that come into contact with them by penetrating the skin or by consuming the flesh of polluted fish living in the polluted water (which also serve as hosts). Inside humans, cercariae develop into sexually mature adults migrating to the lungs (in 3-4 days). After penetration of the pulmonary capillaries the worms are carried into the blood stream. In the hepatic circulation schistosomes mature to adults and in pairs they migrate to the mesenteric veins (*S. japonicum* and *S. mansoni*) or to the vesical plexus (*S. haematobium*).

After 35 days (*S. japonicum*, *S. mansoni*) or 70 days (*S. haematobium*) the mature eggs are excreted in faeces and/or urine to begin the cycle once again.

### 1.3 Helminthiases

Globally it is estimated that there are almost 1,400 people suffering from helminthiases [3], almost all of them in developing countries. Helminthiases are common in regions where poverty and poor sanitary conditions prevail. Under such circumstances the incident rates may reach 90% [4]. There are several kinds of helminthiases named after the helminth causing them. Ascariasis is the most common one and is endemic in Africa, Latin America and the Far East, although the morbidity rate varies according to the region. Almost 73% of *A. lumbricoides* infections occur in Asia, while about 12% occur in Africa and only 8% in Latin American [5]. Even though the mortality rate is low, most of the people infected are children under 15 years with problems of faltering growth and/or decreased physical fitness. Children infected with *Ascaris* have proven to be lower in weight and height and have lower haemoglobin concentration and I.Q. than the control group [6]. Around 1.5 million of these children will probably never bridge the growth deficit, even if treated. Helminthiases are transmitted through: (a) the ingestion of polluted crops, (b) contact with polluted sludge, faeces or wastewater, and (c) the ingestion of polluted meat.

Symptoms are different for each helminthiasis, but in general they are characterized by haemorrhages, deficient blood coagulation and undernourishment. Helminthiases can degenerate into cancer tumours. During its migration, *Ascaris* produces allergic reactions (fever, urticaria and asthma). Once back in the intestine, *Ascaris* produces abdominal pain, meteorism, nausea, vomiting, diarrhea and undernourishment.

As mentioned, helminthiases especially affect children. Morbidity rates are higher among the 5-15 year old population and declines markedly in adults. Adults continue to be infected, but their "worm burden" is not as significant, suggesting the development of some level of immunity. Re-infections studies show that when people have been kept free of infection through regular use of anthelmintic drugs, the prevalence of the infections may increase above the pre-treatment value after treatment ceases.

In addition, individuals show statistically significant correlations in the numbers of worms harboured after several rounds of treatment [7]. Therefore, sanitary programmes based only on medical drugs are not enough to control heminthisases; wastewater and sludge treatment also need to be practiced. Additionally, long-term chemotherapy may have negative effects if sanitary conditions are not addressed.

### 1.4 Morbidity data

Helminthiases diseases are poorly recorded due to the lack of economical, technical and human resources in places where they are dominant. Data comes mainly from the medical reports of public facilities where helminthiases are identified through the patient's symptoms rather than by using laboratory analysis. Thus, helminthiases are frequently poorly and globally reported (as worm diseases) without indicating the specific type of helminth involved.

## 2. Helminth eggs

A common characteristic of helminths is that they reproduce through eggs. The eggs are different in shape and size depending on the genera (Figure 2). The helminth eggs of importance in the sanitary engineering field frequently measure between 20 and 80 μm, although some are as long as 185 μm (schistosomonas). The density of the eggs is greater than that of the water (1.056-1.237) and their structure is gelatinous making them very sticky.

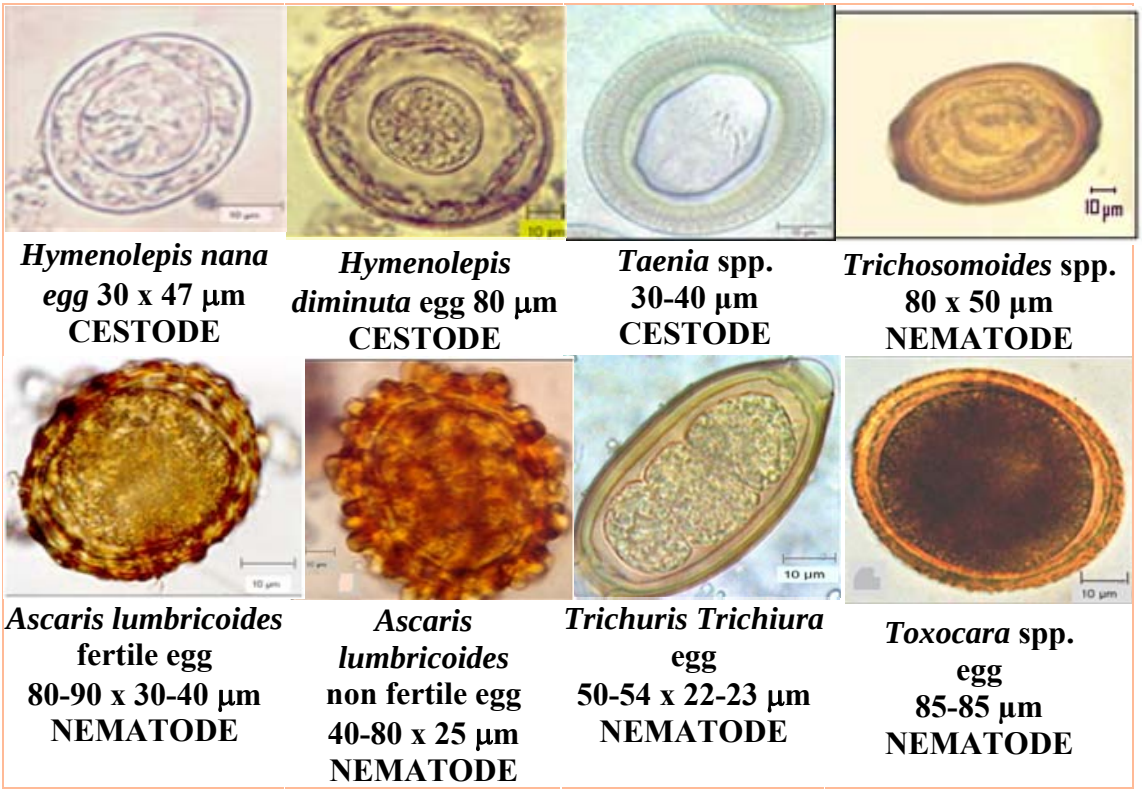



**Fig. 2** Helminth eggs observed in wastewater and sludge
Courtesy of the Treatment and Reuse Group, UNAM [8]

### 2.1 Resistance

Helminth eggs are considered to be the most resistant biological particles in the sanitary engineering field. This resistance is due to their shell, which is comprised of several layers (3-4 depending on the genera). There is an external irregular lipoprotein layer bounded by a trilaminate membrane, a middle chitinous variable thick layer formed with proteins and an inner lipoidal layer [9, 10]. The middle layer, divided by some authors into several ones, serves to give structure and mechanical resistance to the eggs.

The protein layer is an important barrier preventing the passage of material through the shell. The innermost one, which dissolves in organic solvents, is known as the vitelline or ascaroside layer, and also confers resistance. It is particularly resistant to salts and chemicals which are lethal to other microorganisms [11]. This layer is also useful for protecting eggs from desiccation, strong acid and bases, oxidants and reductive agents as well as detergent and proteolytic compounds. The permeability of the shell is limited to the passage of respiratory gases and lipid solvents, although water may move slowly through it. Changes in the permeability of the shell occur during hatching owing to the breakdown of the lipid layer [12, 13]. It is at this stage that it is easiest to inactivate helminth eggs.

### 2.2 Survival time

According to the available information obtained using a less sensitive helminth ova quantification technique than the one available currently, it was found that helminth eggs live in water, soil and crops for several months and over periods that are much longer than those reported for other microorganisms (see Table 1).

**Table 1** Survival time of different pathogens in soil and crops [14]

| Organisms | Soil | | Crops | |
|---|---|---|---|---|
| | Absolute Maximum | Common Maximum | Absolute Maximum | Common Maximum |
| Bacteria | 70 days | 20 days | 30 days | 15 days |
| Viruses | 100 days | 20 days | 2 months | 15 days |
| Protozoan Oocyts | 20 days | 10 days | 10 days | 2 days |
| Helminth ova | Many months | Many months | 2 months | 1 month |

Note: Periods of time may vary according to weather conditions.

### 2.3 Infectivity

As mentioned, helminths eggs found in wastewater are not normally infective. To become so they first need to be viable and second to develop a larva. Viability in wastewater, sludge and faecal sludge is variable and depends on environmental conditions. Unfortunately, there are few data on this, but of 440 samples performed in wastewater viability turned out to be 74 % ± 8.3 and in raw sludge it was 83 ± 21.4 globally (but 90% for *Ascaris* [15]). In contrast, in faecal sludge viability is very variable depending on the amount of time the sludge has been stored, the temperature and the material added to the faeces; unfortunately, little data is available on this. Additionally, latrines possess conditions favouring the development of larva. For instance, Jimenez et al. [16] reported that in sludge coming from an ecosan system (a type of dry latrine) 65% of the eggs were embrionated making them easier to destroy.

Conditions which favor the development of larva are not well established, particularly where each genera of helminth is concerned. Viability in laboratory conditions is measured by incubating the eggs in a slightly acid solution at 26$^{o}$C during 1 month [17-19].

Due to the sticky nature of the eggs they can adhere to utensils, furniture, money, fruit, vegetables, door handles and fingers of endemic areas [20], increasing the infection risk. A study performed in an endemic area revealed that 9-20 *Ascaris* eggs per year were usually ingested through the pathways described above [21]. A comparison between the estimated exposure and the observed worm burden suggests that between 12 to 90% of the eggs ingested developed into worms [7].

### 2.4 Analytical technique

The identification of helminths and helminth eggs in stools are beyond the scope of this chapter but information can be found in Ayres [22]. Environmental samples (wastewater, sludge and faecal sludge) are analysed without using and international standardized technique.

Analytical techniques for enumerating helminth ova can be classified into two: direct and indirect methods [23]. Direct techniques have two general steps. The first one consists of separating, recovering and concentrating helminth ova from the sample. In the second one, the helminth ova are identified and counted visually using a microscope and a Doncaster or a Sedwig-Rafter chamber.

Although these techniques are useful for all kinds of helminth eggs, most of the laboratories only report the *Ascaris* content, not the total helminth ova content indicating the different types of genera observed. Furthermore, each analytical technique has different recovery percentages [24] and care must be taken to report the values obtained mentioning also the method used to obtain them.

Indirect techniques for measuring helminth eggs are used only in liquid samples. Their principle is based on measuring an alternative parameter that can be correlated to the helminth ova content using a previously established calibration curve. Two parameters have been used for this purpose: the suspended solids (Figure 3) and the particle content. Besides being easy to perform, indirect techniques have the advantage of being considerably cheaper (10-20 times less [25].

To determine viability there are two alternatives. The first one consists of incubating the samples used to quantify the eggs at 26ºC during 3-4 weeks. Eggs forming larva are then identified using a microscope. Alternatively, the sample used for the quantification is dyed using different stains (such as tryplan blue, tetrazolium, safranine [26, 27]. Viable eggs become coloured and are identifiable within minutes.

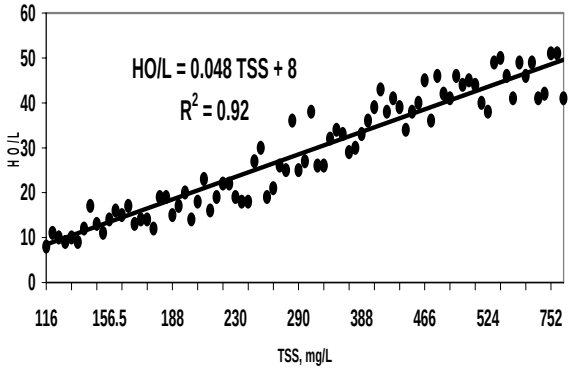



**Fig. 3** Correlation between helminth ova content in Mexico City's wastewater [28]

## 3. Control strategy

A well structured control strategy needs to be based on: (a) local and accurate data concerning the epidemiology, (b) definition of targets, (c) definition of appropriate chemotherapy and health education campaigns, (c) sanitation, (d) monitoring and (e) evaluation programmes [29]. Additionally, schistosomiasis measures to control snails (with spraying and drip feeding) should also be considered. All these components need to be integrated into the prevailing system of primary health care and must be based on multisectoral collaboration [30], a goal often difficult to carry out in practice, which is why it is common to find control programs based only on some of these elements and with limited results.

There are two types of basic control programs: (a) those oriented to treating patients (chemotherapy) and (b) those oriented to cutting the oral-faecal exposure (sanitation). In practice, both are needed. Control programs based on sanitation aim to reduce or interrupt transmission, prevent re-infection and gradually reduce worm loads [21]. But to be effective in a short period of time they need to be combined at their first stage with chemotherapy. Long term ant control programmes need to add elements to improve the economic conditions of a region, to ensure a reliable and permanent sanitation system (access to safe water and appropriate wastewater and sludge disposal system) and have permanent health education programmes. Unfortunately, in most developing countries chemotherapy is the only programme applied for economical and practical reasons based mainly on short-term analysis.

### 3.1 Chemotherapy

These programmes consist of the mass treatment of a large segment of population with drugs. The choice of an appropriate antihelmintic drug depends on (a) its safety record; (b) its therapeutic effect (cure rate or efficacy), (c) its spectrum activity; (d) local health policy; and (e) financial considerations. A key issue for the optimal use of an anthelmintic drug is to decide when and how frequently to treat the population of concern. Common drugs used are albendazole, pyrantel, mebendazole, tiabendazole, niclosamide, pyrantel pomoate and lavamisole. From an economic point of view, targeted population chemotherapy programmes are half the price of universal ones [7]. The fact that long-term chemotherapy programmes are not efficient is often overlooked, as when stopped, if proper sanitation systems have not been put in

place, individuals' vulnerability to worms increases, both in terms of infectivity (predisposition to catching the diseases) and intensity (number of worms developed per individual) [7].

### 3.2 Sanitation

#### 3.2.1 Norms

As mentioned, not all wastewater and sludge contain significant amounts of helminth ova (Table 2). For this reason they are not considered in all countries' wastewater and sludge norms, unlike organic matter or faecal coliforms, which are universal pollution parameters. Based on epidemiological studies, WHO [31] recommends a criteria of $\leq 1$ HO $L^{-1}$ to irrigate with wastewater, without using dripping irrigation, crops that are eaten uncooked. When drip irrigation is used on high growing crops (those growing above the soil) there is no such limitation. For fish culture using wastewater or faecal sludge, the trematode eggs content is limited to zero, because as explained these worms multiply in their first intermediate aquatic host (a snail) by thousands producing millions of eggs before infecting fish or humans. For sludge, biosolids or faecal sludge intended for agriculture use, WHO establishes a criteria of < HO/g TS.

This is a value higher than the US-EPA [32] standard set for biosolids Class A (sludge with no restriction of use) which is 0.25 HO/gTS, but higher than the one set in the same legislation for biosolids Class B (treated sludge that can be used for agricultural purposes under defined circumstances) which has no limits on helminth ova. But for Biosolids class B, in the worst-case scenario sludge will contain a maximum amount of eggs/gTS since is the maximum content found in that country. Copying US-EPA biological limits for biosolids class B in developing countries could be dangerous sludge because: (a) the established faecal coliform content does not reflect that of helminth ova, and (b) the initial helminth ova content is these countries is considerably higher.

**Table 2** Helminth ova content in wastewater and sludge from different countries.

| Country/region | Municipal wastewater HO $L^{-1}$ | Sludge HO $g^{-1}$ TS | |
|---|---|---|---|
| Developing countries | 70-3000 | 70-735 | |
| Tropical countries | | 300-3000 | [33] |
| Brazil | 166–202 | 75 | [34] |
| Chine | 840 | 2300 | [35] |
| Egypt | 6-42 | Mean: 67; Maximum: 735 | [36] |
| Ghana | No data | 76 | [34] |
| Island of Grand Cayman | 100-1230 | No data | [37] |
| Jordan | 300 | No data | |
| Mexico | 6–98 in cities<br>Up to 330 in rural and peri-urban areas | 73-177 (viable eggs) | [34] |
| Morocco | 840 | No data | [38] |
| South Africa | 772 | | [39] |
| Syria | 800 | | [40] |
| Tunisia | 30 | No data | [41] |
| Ukraine | 60 | No data | [14] |
| France | 9 | 5-7 | [34] |
| Germany | No data | < 1 | [34] |
| Great Britain | No data | < 6 | [34] |
| Japan | 80 | 1-51* | [42] |
| United States | 1-8 | 2-13 | [34] |

* No recent data was found. Maximum values may be lower at the present time due to an improvement in sanitary conditions since the date of the report.

The genera found in helminth ova and their proportion in wastewater and sludge also varies according to each country, reflecting local helminthiases. Because Ascariasis is the most common helminthiasis, *Ascaris* eggs are the most common in wastewater and sludge. They represent 71% to 85% in samples from developing countries [24, 43, 44] and are almost the only ones found in those from developed countries [2, 45].

### 3.2.2 Helminth ova removal from wastewater

Unlike other microorganisms commonly contained in wastewater and sludge, due to their high resistance, helminth ova cannot be inactivated with chlorine, UV light or ozone, which are the processes conventionally used to disinfect. Actually, helminth eggs are normally removed from wastewater to be inactivated in sludge.

To remove helminth ova from wastewater processes removing particles are useful (sedimentation, filtration and coagulation-flocculation). Table 3 contains efficiency rates for several processes. For those countries with a high helminth ova content in their effluents several processes must be combined in order to achieve the recommended limit of 1 HO/L, which is, in fact, very low. Alternatively, as recommended by WHO [31], methods complementing wastewater treatment options can be used to control health risk to acceptable values, such as the type of irrigation method, produce disinfection/washing, type of crops irrigated.

**Table 3** Reduction or inactivation removal of organism by selected wastewater treatment processes. With information from: [23, 31, 41, 46-48].

| Treatment process | Removal, % Helminth Eggs |
|---|---|
| Waste stabilization ponds | 78-99(1)(5)(6) |
| Wastewater storage and treatment reservoirs | 90-99(1)(4) |
| Constructed wetlands | 90?(1)(5) |
| Primary sedimentation | 0–<1(1) |
| Chemically enhanced primary treatment | 90-99(1)(5) |
| Anaerobic up flow sludge blanket reactors | 75-96(1)(6) |
| Activated sludge + secondary sedimentation | 85-95(1) |
| Tickling filters + secondary sedimentation | 80-90(3) |
| Aerated lagoon or oxidation ditch + settling pond | 85-90(3) |
| Coagulation/flocculation as tertiary treatment | 99(1) |
| High-rate granular or slow-rate sand filtration | >99(1) |
| Dual-media filtration | 99(3) |
| Sand dunes infiltration | 100 |
| Membrane bioreactors | >99,99(3) |
| Chlorination (free chlorine) | 0–20(1) |
| Ozonation | 0-20(2) |
| UV irradiation | 0(2) |
| Photosensitized porphyrin | 90 (2) |

[a] The log unit reductions are $\log_{10}$ unit reductions defined as $\log_{10}$(initial pathogen concentration/final pathogen concentration). Thus a 1-log unit reduction = 90% reduction; a 2-log unit reduction = 99% reduction; a 3-log unit reduction = 99,9% reduction and so on.
(a) Tested with up to 2 log initial content. Might have greater efficiencies than reported
(1) Have been tested on a full scale
(2) From laboratory data

(3) Theoretical efficiency based on removal mechanisms
(4) Total helminth egg removal is only achieved when wetlands are coupled with a filtration step
(5) Tested with high helminth egg content
(6) Several references used

#### 3.2.2.3 Helminth ova inactivation in sludge

In sludge and faecal sludge, ova are inactivated by raising the temperature, lowering moisture or adding very specific disinfectants. For developing countries (with helminth ova contents of 70-735 HO/gTS) WHO criteria of 1 HO/gTS implies having processes with efficiencies of 98,6 to 99,9%. Unfortunately: (a) few economically affordable processes have these efficiencies; and (b) most of the efficiency data reported have been obtained for sludge with initial low helminth ova content and cannot be used with the same results on sludge with a higher one, as demonstrated by Mendez et al. [49] for lime stabilization.

Temperature is supposed to inactivate eggs if it is raised above 40ºC, but the amount of time the eggs should remain under these conditions is not specified. According to Capizzi-Banas et al. [50] (2004), 128 minutes are required to inactive 92 *Ascaris* eggs/gTS at 50ºC, while at 54ºC with a high pH attained by adding lime to sludge, 45 minutes are needed and 4 minutes at 66,1 ºC. For *Ascaris* US-EPA [32] in sludge with a low helminth ova content the contact time should be 10-20 days at temperatures of above 40ºC for digesters. Besides inactivating helminth ova increasing temperature produces a sludge that is easy to dewater and is more stable. Moisture below 5% (TS > 95%) also inactivates helminths, although detailed conditions on the exposure time have not been reported. Processes for inactivating helminth ova in sludge are shown in Table 4.

**Table 4** Helminth ova inactivation efficiencies reported for different sludge treatment processes.

| Processes | Helminth ova inactivation | |
|---|---|---|
| Lime postabilization | 100% from an initial value of 8 HO/L | [51] |
| Lime Stabilization | 100% with slaked lime heated to 50ºC during 48 min with an initial content of 70 *Ascaris*/gTS | [50] |
| Quick Lime postabilization | At ph 12 for 2 hours<br>65-92% using 20-40% lime in w/w | [49] |
| Mesophilic digestion | With 15 days retention time at 35-55ºC or 60 days at 20ºC less than 30 % | [34] |
| Thermophilic aerobic digestion at 48 ºC | Reduction from 4,5 ± 3,2 to <1 viable ovum/10g TS in 30 days, an average efficiency of 78%. | [52] |
| Thermophilic anaerobic digestion at 45-65ºC | 75 to 78% with HO of around 80 eggs/gTS | [53] |
| Thermal treatment at 108ºC | 90-93% with an initial content of 9,5 HO/gTS | [52] |
| Irradiation at 750 Gy | 100% inactivation with an initial content of up to 100 HO $g^{-1}$ TS | [17] |
| Irradiation at 1000 Gy | 100% inactivation with an initial content of 88 HO $g^{-1}$ TS | [54] |
| Pasteurization at 70ºC | 100% with an initial value of 8 HO $g^{-1}$ TS | [51] |
| Acid treatment with peracetic acid | 95% with an initial content of up to 100 HO $g^{-1}$ TS | [55] |
| Thermal Dry of Sludge Anaerobic Digested | 100% sludge with initial high helminth ova content from Brazil | [56] |
| Co-composting | 70-100% from initial content of 22-83 egss/gTS, eggs have 20% viability | [57] |

Stabilization ponds are a frequently recommended process for removing helminth ova from wastewater. Eggs accumulate in the ponds sediments and when sludge is removed from ponds a material

with a variable helminth ova content and viability is obtained (Table 5) and needs to be carefully managed.

**Table 5** HO content in sludge extracted from stabilization ponds

| Country | Type of WW | Content | Reference |
|---|---|---|---|
| Campina Grande Brazil | Experimental WSP in series | 1000 eggs/L | [58] |
| | Biosolids from and experiments l WSP in series | 1400-40000/gTS with a viability of between 2-8% | [58] |
| Toluca, Mexico | Waste stabilization ponds sludge | 48-136 eggs/gTS with a viability from 0-50% | [59] |
| Asia | Sludge from a constructed wetland | 170 eggs/gTS<br>Viability of 0,2-3,1% after 3.5 years | [60] |
| Chiclayo, Peru | WSP in series | 10-40 eggs/L | [61] |
| | Sludge from a primary facultative ponds | 60-260 eggs/gTS with 1-5% viability after 4-5 years | |

3.2.2.4 Helminth ova inactivation in faecal sludge

Controlling helminth ova content in rural areas of poor countries is a particular challenge because: (a) very high helminth ova content is found; (b) it is practically impossible to perform periodic surveys; (c) treatment processes need to be low cost and simple to operate; and (d) there is very little research and information on the subject. Dehydration is the most common method used in some on-site sanitation systems but displays contradictory results on helminth ova inactivation (Table 6). Dehydration is performed only through storage, sometimes by adding dry material or using solar energy. It seems that only by storing faeces for more than 1-2 years with a TS content > 50-60% achieved by adding bulking agents (lime, earth, leaves, etc.) and at a temperature above 30$^{o}$C, can helminth ova be inactivated.

**Table 6** Helminth ova content in sludge of on site sanitation systems with different operating conditions. Adapted from: [23, 57, 62].

| HO $g^{-1}$ TS | Sludge type |
|---|---|
| 670-2000 | Fresh sludge coming from public systems or from latrines with a storage time of days to weeks |
| 580 | Sludge from septic tanks stored for several years |
| 300 | Feces from dry sanitation systems from Guatemala, with a 1 year storage at a high pH and a temperature of between 17-20$^{o}$C |
| 35-232 eggs/gTS | Fresh sludges from public septic tanks in Kumasi, Ghana |
| 18-162 eggs/gTS | Fresh sludges from public toilets in Kumasi, Ghana |
| O *Ascaris*/gTS | Sludges coming from various urine diversion toilets stored for 20 months in plastic containers from Eastern Cape in South Africa |
| 0 viable *Ascaris* $g^{-1}$ TS | Sludge from dry sanitation systems in El Salvador, solar dried at 34-44$^{o}$C and stored for a long period of time |
| 0 *Ascaris* $g^{-1}$ TS | Sludge from dry sanitation systems in South Africa stored for 20 months in plastic containers |

Even though helminths are still a major health concern in several regions of the world, little information about their characteristics, content in wastewater and sludge and behaviour during different treatment processes is available owing among other things to a lack of research in both developed and developing countries, and hence controlling them is difficult.

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