Wastewater Biology
Parasites

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Definitions

• A parasite lives on *ectoparasite* or in *endoparasite* another organism of a different species from which it derives its nourishment. This organism is the parasite *host*.

• The host in which the parasite reaches sexual maturity and reproduction is usually termed the *definitive host*.

• An *intermediate host* is one in which some developmental or larval stage of the parasite occurs.

• A *reservoir host* is another animal (besides man) in which the parasite can use to complete its life cycle.
Reasons for Increased Attention to Transmission of Protozoa and Helminths in Wastewater

- Recognition of increased parasitic infestations in U.S.
- Return of military personnel and travelers from abroad
- Increased level of immigration in U.S.
- Food imported from countries with high parasitic disease prevalence
- Existence of resistant stages of parasites
  - Helminth eggs
  - Protozoan cysts
Parasites of concern

• Protozoa

• Helminths (worms)
  – Flatworms (flukes and tapeworms)
  – Roundworms (nematode worms)
Risk of Infection is Real!

- Variety of parasites live in domestic wastewater and they can present an occupational health hazard.
- WEF survey incidence for disabling parasitic illness is < 1 - 2%
Survey of 75 Municipal Plants
(Location: Alabama, Florida, Louisiana, Minnesota, Mississippi, New York, Ohio, Texas and Washington)

- Resistant stages of 23 types of parasites were found in samples, which may represent over 30 different human and animal parasites.
  - Densities may vary, parasites are distributed throughout all of the continental US.
  - 4 most common parasite were the nematodes, *Ascaris spp.*, *Trichuris*, and *Toxocara spp*.
  - Total number of parasite ova recovered varied according to the source of sludge and season of the year and averaged 14,000 eggs/kg (dry weight) of sludge.
• Percentage of total parasite ova in the sludge sample that were viable (infection causing capability) ranged from 0 – 100%, but was generally greater than 45% for primary sludge and 69% for treated sludges

• Primary and secondary undigested sludge samples were found to contain in order of decreasing average densities 9,700 *Ascaris* spp. ova, 1,200 *Toxocara* spp. ova, 800 *T. trichiura* ova, and 600 *T. vulpis* ova/dry kg of sample

• Average number of these parasites in stabilized sludge samples were 9,600 *Ascaris* spp. ova, 2,600 *T. trichiura* ova, 700 *Toxocara* spp. ova, and 700 *T. vulpis* ova/dry kg of sludge sample
Major Transmission Areas for Parasitic Protozoa

- Wastewaters
- Sludges
- Sludge-amended soils
- Sludge disposal sites
Minor Transmission Areas for Parasitic Protozoa and Helminths

- Aerosols
- Groundwater

Why? Because size and weight of protozoan cysts and helminth eggs
  - Hinder their conveyance on aerosols
  - Hinder their movement through soil in groundwater
Parasites

Figure 166. Cyst of *Giardia* sp. (arrow), ~10 μm in length, from primary sludge, Alabama. These are parasitic flagellates that live in the small intestine of vertebrates. Resistant cysts, which serve to infect the next host, are passed out with feces.

Figure 168. Cyst (arrow) of *Giardia intestinalis* (=*lamblia*), ~12 μm in length, stained with hematoxylin. This species infects humans. The active flagellates in the intestine have two nuclei and eight flagella. After encystment, the nuclei divide, so that four nuclei are present in cysts. Several are in the plane of focus here. The other darkly-staining structures in the cyst are microtubular bands and fragments of the sucking disc with which it attaches to the intestinal wall.

Figure 167. Same as Figure 166 except dead.

Figure 169. *Entamoeba coli* cysts, ~10 μm in diameter, from sludge, Washington. These amoebae live as commensals in the intestine and eat bacteria without doing harm to their host. There are several rounds of nuclear division after encystment, so that mature cysts contain eight nuclei. They can be distinguished from *E. histolytica*, the causative agent of amoebic dysentery in humans, by the number of nuclei in cysts. *E. histolytica* cysts contain four nuclei.

Figure 170. *E. coli*-like cyst, ~12 μm in diameter, from primary sludge, New York.

NOTE: All photographs of parasites except for Figures 168 and 172 were contributed by Dr. M. Dale Little of Tulane University.

Figure 171. Coecidian oocyst, ~12 μm long, from sludge drying bed, Alabama. When an oocyst is swallowed by an appropriate host, sporozoites inside will emerge in the intestine and begin multiplying in the cells of the intestinal epithelium. Many species of coecidia exist, identification of this species is not possible from this photograph.
Figures 172, 173. Cryptosporidium parvum oocysts (round structures) and sporozoites (smaller cylindrical structures with rounded ends) from cattle feces. Oocysts = 5 μm in diameter; sporozoites = 3 to 5 μm long. Differential interference contrast. This species is a coccidian parasite that can infect humans causing a self-limiting diarrhea. It can be more serious for immunocompromised individuals. Sporozoites would not survive outside the oocyst in wastewater. The oocysts of this photograph were placed in an excystation medium, so that sporozoites would be released.

Figure 173. Egg of the trematode Schistosoma mansoni, 125 μm long, from primary sludge, New York. The adult worms parasitize humans, living in the blood vessels surrounding the large intestine. Their eggs migrate through tissue to reach the lumen of the intestine, after which they are passed out in the feces. The larvae hatch from the egg in water and must find an aquatic snail of the genus Biomphalaria for the life cycle to continue. It bores into the snail tissues and begins growing. It produces large numbers of cercariae (a motile swimming stage that leaves the snail) that penetrate the skin of humans wading in the water and then migrate to the blood vessels around the large intestine, where they reach maturity. It is common in Africa and the New World tropics. Although different sanitation standards and the absence of the appropriate snail host prevent transmission from occurring in the continental U.S., it is still found here, as it is brought in by travelers and immigrants.

Figures 174, 175, 176. Egg of the tapeworm Diphyllobothrium latum, 60 μm long. Figure 174 from primary sludge, Minnesota; Figure 175 from human feces, preserved; Figure 176 from primary sludge, New York. The egg has an operculum on one end and a barely developed knob at the other, features that are most apparent in Figure 175. The swimming larva that emerges from the egg survives only if eaten by a copepod. It bores through the intestinal wall and takes up residence in the hemocoeel. If the copepod is then eaten by a fish, the tapeworm larva migrates to the muscle and grows further. They can be seen as white blobs in the meat of freshly caught fish. The life cycle is completed when a predator consumes the fish; the tapeworm reaches maturity in the intestine of the predator. D. latum is a common human parasite throughout the world. In the U.S., it is most common in the Great Lakes area.
Figures 178-184. Development of an Ascaris egg. The nematode *Ascaris lumbricoides* is a common human parasite that lives as an adult in the intestine. The eggs, about 60 μm long, are characteristically bumpy and brown. People become infected by ingesting eggs containing a young worm (Figure 184). Rather than remaining in the intestine, the worms migrate to the lungs. After crawling up to the throat from the lungs or being coughed up, the worms are reswallowed, and this time they stay in the intestine where they grow into adult worms.

Figure 177. Egg of the tapeworm *Hymenolepis diminuta*, 90 μm long, from primary sludge, Washington. It will hatch after being ingested by a grain beetle, and the larvae will bore through the intestinal wall using the six hooks visible in the photograph. It will settle in the hemocoel and wait for a rat or human to ingest the beetle. After ingestion by a rat or human, the tapeworm will grow to maturity in the intestine.

Figure 178 from anaerobic digester, New York. Figure 179 from sludge, source unknown. Figure 180 from sludge drying bed, Alabama. Figure 181 from primary sludge, New York. Figure 182 from primary sludge, New York. Figure 183 from activated sludge, Washington. Figure 184 from sludge drying bed, Florida.
Figure 185. Egg of *Parascaris equorum* from anaerobic digester, Washington. This is an ascarid parasite of horses and has the same life cycle as *A. lumbricoides*.

Figure 186. Nematode egg (*Ascaridia* sp. or *Heterakis* sp.) from poultry waste, Alabama.
Figures 187–192. Development of a *Toxocara canis* egg. This ascarid parasite of dogs has the same life cycle as that of *A. lumbricoides* when it infects puppies. In adult dogs, the larvae cannot complete migration to the lungs. They survive in the tissues for a while before dying. Figure 187, *T. canis* surface, from primary sludge, Minnesota. Figure 188, two-cell stage, from anaerobic digester, Washington. Figure 189, four-cell stage, from raw sludge, New York. Figure 190, eight or more cells, from sludge drying bed, Alabama. Figure 191, early larval stage, from primary sludge, New York. Figure 192, infective stage, source unknown.

Figure 187

Figure 188

Figure 189

Figure 190

Figure 191

Figure 192
Figures 193, 194. Dead *T. canis* eggs. Figure 193 from activated sludge, New York. Figure 194 from drying bed, Alabama.

Figures 196–199. Development of *Trichuris trichiura* egg. This nematode parasite of humans is sometimes called a whip worm, because it has a long thin anterior end and a short fatter posterior end—the whip handle. Adults live in the intestine, and eggs are passed in feces. Humans become infected by ingesting eggs. Figure 196, two-cell stage, from aerobic sludge, Alabama. Figure 197, eight-cell stage, from anaerobic digester, New York. Figure 198, *T. trichiura* viable egg from primary sludge, New York. Figure 199, infective egg, source unknown.

Figure 195. Egg of *Toxocara canis*, which infects cats, from Imhoff tanks, New York. Egg is in the two-cell stage. *T. canis* eggs are 80 to 90 μm in diameter.
Figures 200–203. Eggs of *T. vulpis*, the dog whipworm. **Figure 200** from drying bed, Mississippi. **Figure 201**, two-cell stage, from anaerobic digester, New York. **Figure 202**, viable egg in the eight-cell stage, from primary sludge, New York. **Figure 203**, infectious stage, from drying bed, Florida.

**Figure 204.** Egg of the rat nematode *Trichosomoides* from anaerobic digester, Washington.

**Figures 205, 206.** Unidentified nematode eggs from raw sludge, New York.
Frequently Asked Questions & Answers about Wastewater and Biosolids Worker Health & Safety

Do wastewater and biosolids workers have a higher rate of potential exposure to pathogens than the general public?

A common characteristic of untreated wastewater is its high concentration of microorganisms. Biological secondary treatment followed by disinfection is an important way to treat wastewater because it significantly reduces microorganisms. The disinfection process that follows then kills many pathogens before the cleaned water is discharged to the receiving streams. Because of their daily exposure and contact with biological materials, wastewater personnel may have a higher incidence of potential exposure to pathogens than the general public. For most workers, however, the risk of developing an occupational illness is significantly reduced or eliminated when standard safety and personal hygiene procedures are followed.

What are some of the common wastewater facility hazards?

As in many occupational settings ranging from hospitals, restaurants, food processing, agriculture, and health-care professions, wastewater personnel can also be potentially exposed to biological hazards. Even routine procedures such as changing a baby’s soiled diaper and preparing meat dishes can expose an individual to contamination if proper personal hygiene is not followed. Some of the potential hazards for individuals who work around any collection system or wastewater facility may include: infectious disease, physical injury, confined spaces, oxygen-deficient spaces, toxic or harmful chemicals and gases, explosive gas mixtures, fires,
electrical shock, noise, and dust and fumes. It is important, therefore, that workers follow standard safe work procedures to minimize or eliminate the potential for injury and illness.

What are some of the health and safety concerns with biosolids composting?

The major wastewater worker health and safety concerns involve the potential effects of primary pathogens, bioaerosols, heavy metals, and other microorganisms at facilities processing wastewater and biosolids. Worker exposure could occur through inhalation, ingestion, and dermal contact. Adherence to good personal hygiene and use of personal protective equipment are recommended for workers in these occupational environments.

Have there been any studies relating to the incidence of illness to wastewater workers?

Studies have been conducted over the past 25 years relating to wastewater worker occupational illnesses. Although most studies cited in the scientific literature indicate that infections from specific agents are not common, workers in contact with wastewater or biosolids, especially during their first few years of employment, have been known to experience some increased symptoms associated with gastrointestinal or upper respiratory illnesses. However, other studies also point out that wastewater workers build immunity over time against these types of illnesses and are generally healthier than the general population.

What can wastewater workers do to minimize potential exposures to pathogens?

Proper personal hygiene and use of personal protective equipment are critical because infections from contact and exposure to microorganisms may occur without symptoms and antibodies to bacteria and viruses may
develop without illness symptoms being readily apparent.

What are the most common bacterial pathogens found in wastewater?

The most common bacterial pathogens found in untreated wastewater are *Salmonella* and *Shigella*. Other bacterial microorganisms include *Vibrio*, *Clostridium*, *Yersinia*, *Campylobacter*, and *Leptospira*. *Escherichia coli* (*E. coli*), which can cause gastroenteritis, is generally not considered a pathogen because it is a microorganism that naturally inhabits the gastrointestinal tract of man.

What is the difference between a virus and bacteria?

A virus is any group of ultramicroscopic agents that reproduce only in living cells. Unlike viruses, bacteria do not require a living host cell to reproduce. Pathogenic bacteria are microscopic in size and common in wastewater. Because bacteria can reproduce outside the body, microorganisms can be present in large quantities in the wastewater collection system and treatment process.

What types of viruses are found in wastewater?

Viruses multiply in the living cells of the intestinal tract and end up in human feces. The common human viruses in wastewater include *Norwalk*, *Rotavirus*, *Adenovirus*, *Coxsackie A and B*, *Echovirus*, *Hepatitis A*, *Poliovirus*, and *Reovirus*. These viruses have the potential to cause gastrointestinal and upper respiratory illness when proper safety procedures are not followed in the workplace.
Can parasites be found in wastewater?

Waterborne parasites found in wastewater consist of various types of protozoa and worms. Many of these organisms often do not survive the journey through the wastewater collection system and treatment facilities. The cysts and eggs, in which the protozoa and worms reproduce, are often resistant to adverse conditions and may show up in wastewater or biosolids samples. Because hand-to-mouth contact is the principal cause of infection, it is important that workers wash their hands frequently.

Are wastewater workers at risk to contracting AIDS or Hepatitis B in the workplace?

AIDS and hepatitis B are both blood-borne viruses and cannot reproduce outside the human body. For disease transmission, AIDS and hepatitis B must enter the bloodstream directly. The Centers for Disease Control (CDC) has stated that there is no scientific evidence that AIDS or hepatitis B can be contracted through occupational exposure associated with wastewater treatment.

What is the most common route of wastewater worker infection?

The most common cause of infection is due to poor personal hygiene. The three basic routes that may lead to infection in the wastewater environment include ingestion through splashes, contaminated food, or cigarettes; inhalation of infectious agents or aerosols; and infection due to an unprotected cut or abrasion. Ingestion is generally the major route of wastewater worker infection. The common practice of touching the mouth with the hand will contribute to the possibility of infection. Workers who eat or smoke without washing their hands have
a much higher risk of infection. Personal hygiene practices including frequent washing of the hands will minimize these potential opportunities for exposure.

**What are the risks of infection to biosolids operators?**

In addition to the general risks to wastewater workers, biosolids workers that are at locations where wastewater or biosolids are sprayed should avoid prolonged exposures where contact with such aerosols are likely. In instances where prolonged exposure to aerosols is anticipated, the use of surgical masks and goggles will significantly minimize contact and risk of infection.

**What can wastewater workers do to prevent infections?**

The most important consideration is the use of good common sense and following appropriate personal hygiene and using personal protective equipment where appropriate. Some of the standard workplace precautions and personal hygiene steps that should be followed include:

- Wash hands frequently with soap and water after contacting wastewater; after visiting rest rooms; before eating, drinking, or smoking; and at the end of the work shift.
- Promptly treat cuts and abrasions using appropriate first aid measures.
- Wear heavy-duty gloves (double gloving) and boots that are waterproof and puncture resistant.
- Wear surgical-type masks and goggles or face shields for prolonged exposure to wastewater aerosols.
- Change soiled uniforms or protective clothing as soon as the job is completed.
- Shower before changing into clean street clothes and shoes.
- Wherever possible, use dual lockers to separate work and street clothes.
- Launder work clothes at work and not at home.
- Handle sharp items with extra care to prevent accidental injuries.
- Clean contaminated tools after use.
- Follow good common sense and exercise extra caution whenever there is contact with contaminated water or sludge.
- Promptly clean body parts that contact wastewater or biosolids.

Do the Centers for Disease Control recommend any special immunizations for wastewater or biosolids workers?

No additional immunizations above those recommended by CDC for the adult general population are advised for workers in contact with wastewater or biosolids. Wastewater and biosolids workers and all other adults in the general population should be adequately vaccinated against diphtheria and tetanus. The preventive effect of the vaccine immune serum globulin for hepatitis A is short lived (about 3 weeks), and is not routinely recommended for wastewater or biosolids workers. This vaccine is only recommended where there has been direct exposure to wastewater splashed into an open wound or the mouth or a severe outbreak has occurred in the community. The vaccine for hepatitis B is not routinely recommended for wastewater or biosolids workers because the risk of transmission of the virus by wastewater is extremely remote.
REFERENCES


Parasitic Protozoa Life Cycle

- Protozoa exists as a trophozoite in intestinal tract of infested individuals.
- Trophozoite is fragile and dies quickly outside the intestinal tract.
- Protozoa survives outside intestinal tract (in feces) as a cyst.
  - Contains a thick hyaline wall (provides environmental resistance).
Factors Affecting Types and Levels of Protozoan Cysts

- Prevalence of disease in contributing human population
- Degree of animal contribution to conveyance system
Parasitic Protozoan That May Be Found in Wastewater

- *Balantidium coli*
- *Dietamoeba fragilis*
- *Entamoeba histolytica*
- *Giardia lamblia*
- *Isospora belli*
- *Isospora hominis*
- *Toxoplasma gondii*
- Others
Major Parasitic Protozoa

- *Balantidium coli*
- *Entamoeba histolytica*
- *Giardia lamblia*
- *Cryptosporidium parvum*
<table>
<thead>
<tr>
<th>Species</th>
<th>Types of Wastewater</th>
<th>Concentration (cysts/L)</th>
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<tbody>
<tr>
<td>1. <em>E. histolytica</em></td>
<td>Untreated</td>
<td>4.0</td>
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<tr>
<td></td>
<td>Effluent</td>
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<td>Untreated 50% prevalence</td>
<td>5000</td>
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<tr>
<td>2. <em>G. lamblia</em></td>
<td>Untreated</td>
<td>80,000</td>
</tr>
<tr>
<td></td>
<td>Untreated 50% prevalence</td>
<td>4,000,000</td>
</tr>
</tbody>
</table>
Entamoeba histolytica

Cysts have four nuclei

Trophozoites encyst in colon

Trophozoites excyst in small intestine

Cysts are passed with feces

Trophozoite

PATHOLOGY

Flask-shaped ulcer

Liver abscess

Brain abscess
Balantidium coli

Reservoir host

Cysts are ingested

Trophozoites excyst in small intestine

Trophozoites invade tissues of the colon

PATHOLOGY

Crater-form ulcer in colon

Cysts pass in feces

Trophozoites encyst in colon
Toxoplasma gondii

Pseudocysts are found in meats

Ingestion of cysts in raw or undercooked infected meat initiates infection

Tachyzoites infect liver cells

Pseudocysts in tissues of mouse

Oocysts pass out in feces

Reservoir hosts

PATHOLOGY

Brain lesions

Chorioretinitis

Hepatitis

Lymphadenitis

Congenital infection

Asexual cycle occurs in all cell types

Infected macrophages distribute tachyzoites throughout body

Pseudocysts are produced in response to acquired immunity
Giardia lamblia Distribution

- Worldwide or cosmopolitan
- United States occurrences
  - Endemic forms (restricted)
  - Epidemic forms (widespread)
- Highest prevalence in the U.S.
  - Communities using surface water supplies
  - Potable water treatment consists primarily of disinfection only
- Locations
  - New England States
  - Mid-Atlantic States
  - Pacific Northwest States
  - Rocky Mountain States
Giardia lamblia

- Flagellated protozoa
- Causative agent for giardiasis or lambliasis
- Giardiasis: infects the small intestine
  - Severe diarrhea
  - Weight loss
- Prevalence in the United States
  - 1.5 to 20%
  - Most cases asymptomatic
- Most frequently identified intestinal parasite in the United States
Giardia lamblia Continued

• Transmission
  – Municipal water supplies
  – Human-to-human contact
  – Contaminated food
  – Remote mountain streams
  – Wastewater contaminated with infected feces

• Reservoir hosts
  – Beaver
  – Muskrat
  – Vole
Life Cycle of *Giardia lamblia*

- Dormant cysts are swallowed
  - Oval
  - ~8 to 14 um long and ~7 to 10 um wide
  - Four nuclei
  - Thick hyaline wall
  - Can survive
    - In most environments for ~2 weeks
    - In mixture of urine, feces, and water for ~1 week

- Cysts undergo excystation in upper portion of small intestine
  - Hyaline wall breaks down
  - Newly formed trophozoites emerge
Life Cycle Continued

• Trophozoites attach to epithelial cells of intestinal wall of small intestinal tract
  – Sucking disks used for attachment
  – Disks resist peristalsis

– Trophozoite structure
  • Pear-shaped
  • ~9 to 22um long and ~5 to 15 um wide
  • Displays bilateral symmetry
  • Has two anterior nuclei
  • Has four pair of nuclei
  • Reproduces by simple fusion
Giardia lamblia

Cysts are ingested

Cysts have 4 nuclei

Trophozoites excyst in small intestine

Trophozoites live on surface of villi

Fecal contamination

Cysts pass in feces

PATHOLOGY
Life Cycle Continued

- Several thousand trophozoites can fit on end of pin
- Trophozoites pass through intestinal tract and encystation occurs, i.e. cysts develop
- Cysts released to environment through feces
# Symptoms of Giardiasis

<table>
<thead>
<tr>
<th>Acute Condition</th>
<th>Chronic Condition</th>
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<tr>
<td>Abnormal cramps</td>
<td>Abdominal cramps</td>
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<tr>
<td>Bleaching</td>
<td>Bloating</td>
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<tr>
<td>Epigastric tenderness</td>
<td>Lethargy</td>
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<tr>
<td>Flatulence</td>
<td>Loss of appetite</td>
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<tr>
<td>Mild diarrhea</td>
<td>Severe diarrhea</td>
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<td></td>
<td>Loss of weight</td>
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<td></td>
<td>Shock</td>
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<td></td>
<td>Ulceration of intestine</td>
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<td>Vitamin deficiencies</td>
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Sampling for Giardia lamblia cysts

• Water supplies
  – Routine coliform counts inadequate for evaluation of presence and number of *Giardia lamblia* cysts, because cysts are extremely resistant to chlorination at generally accepted chlorine residual values
  – Filtration technique for high-volume sampling (HVS) can be employed (current edition of *Standard Methods*).

• Wastewater supplies
  – Examine sludges where cysts are most concentrated
  – Used floatation technique
    • Current edition of *Standard Methods*
    • Parasitology laboratory manual
Cryptosporidium

Oocyst is ingested

Sporulated oocyst

Reservoir hosts

Sporozoites are released from oocyst in small intestine

Sporozoites attach to surface of columnar epithelial cells

Unsporulated oocyst released from cell surface

Macrogametocyte becomes fertilized

Sexual reproduction

Microgametocyte

Transthyzite
Parasitic Helminths

• Parasitic helminths’ complex life cycle
  – Difficult to determine degree of “risk”
  – Difficult to incriminate “occupational risk”
  – Life cycle often has stages tolerating harsh environmental conditions

• Helminths
  – Roundworms (*Ascaris lumbricoides*)
  – Flatworms (*Taenia solium*) - tapeworms and flukes

• Factors affecting genera and levels of parasitic helminth eggs in wastewater
  – Levels of disease in contributing human populations
  – Levels of disease in contributing animal populations
Helminths of Concern

- *Ancylostoma braziliense* – cat hookworm
- *Ancylostoma caninum* – dog hookworm
- *Ancylostoma duodenale* – hookworm
- *Ascaris lumbricoides* – roundworm
- *Ascaris suum* – roundworm
- *Enterobius vermicularis* – pinworm
- *Necator americanus* – hookworm
- *Strongyloides stercoralis* – dog roundworm
- *Toxocara canis* – dog roundworm
- *Toxocara cati* – cat roundworm
- *Trichuria trichuria* - whipworm
Cestodes (Tapeworms)

- *Echinococcus granulosus* - dog tapeworm
- *Hymenolepis nana* – dwarf tapeworm
- *Taenia saginata* – beef tapeworm
- *Taenia solium* – pork tapeworm
LIFE CYCLES IMPORTANT HUMAN TAPEWORMS

ADULTS LIVING IN INTESTINE
- Diphyllobothrium latum
- Taenia solium
- Taenia saginata
- Dipylidium caninum
- Hymenolepis diminuta
- Hymenolepis nana

IN MAN

Eaten by Man
Accidental Ingestion

IN INTERMEDIATE HOST

Eaten by Intermediate Hosts

Various Insects
- Flea
- Cattle
- Hog

Into water
<table>
<thead>
<tr>
<th>Phylum</th>
<th>Class</th>
<th>Order</th>
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<tbody>
<tr>
<td>Scolex</td>
<td>Proglottid</td>
<td>Taenia solium</td>
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<tr>
<td>Taenia saginata</td>
<td>E. granulosus</td>
<td>Hymenolepsis diminuta</td>
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<td>Dipylidium caninum</td>
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<td>D. latum</td>
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IMMATURE STAGES OF HUMAN TAPEWORMS

PSEUDOPHYLLIDEA
- Egg
- Coracidium
- Onchosphère
- Procercoid larva
- Plerocercid or sparganum larva

CYCLOPHYLLIDEA
- Egg
- Embryophore
- Onchosphère
- Cysticercoid larva (found in Hymenolepis and Dipylidium)
- Cysticercus larva (found in Taenia)

Hydatid larva
- Found in Echinococcus
- Scolex
- Multilocular or alveolar cysts

Coenurus larva
- Found in Multiceps
Taenia solium Life Notes

- Average life span for adults ~ 25 years
- Eggs released/day/worm > 10,000
TAPEWORM LIFE CYCLE
Taenia solium

ADULT WORM
MAN - definitive host

1. HUMAN INTESTINE
2. Proglottids
3. Eggs in food eaten by hog
4. Cysticercus (bladder worm)

CYSTICERCUS
HOG - intermediate host

1. Larvae burrow into blood or lymph vessels and carried to muscle
2. Gravid proglottid
3. Mature proglottid
4. Adult tapeworm
5. Cysticercus (everted scolex)
6. Oncosphere (6 hooked embryo)
7. Gravid proglottids pass out with feces
*Taenia solium* (tapeworm) Life Cycle

- Infestation initiated when rare pork containing cysticerci ingested
  - Wastewater and sludges not significant vessels for cysticerci
  - Wastewater and sludges significant vessels for tapeworm eggs
- Adult tapeworm develops and matures in intestinal tract
  - Attaches with sucking discs in scolex
  - Attaches with hooks on scolex
Life Cycle for *Taenia solium*

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Taenia solium (tapeworm) Life Cycle Continued

- Adult tapeworm possesses female and male gonads
  - Eggs develop within proglottids
  - Eggs released with feces
- Egg-contaminated waste fed to pigs
- Oncosphere: embryo from egg
  - Penetrates intestines of pig
  - Enters circulatory or lymphatic system
- Cysticercus develops in pig muscle
- Cysticerci consumed by man
**Taenia solium**

Cysticerci are ingested with raw or undercooked pork

Embryonated eggs eaten by pig; larvae migrate to tissues, develop to cysticerci

Cysticerci in muscle tissue

Adults grow to ~10 m in length

Gravid proglottid

Proglottids pass in feces

Worms mature in small intestine

Cysticerci are released from muscle in stomach

Adults live in small intestine

Scolex contains hooklets and four suckers

JNK
Cysticercosis

Embryonated eggs are ingested

Larvae hatch in small intestine

Larvae migrate to all organs

Cysticercus in muscle

Cysticercus in eye

Cysticerci in brain
LIFE CYCLES OF IMPORTANT HUMAN FLUERES

ADULTS LIVING IN MAN

1. Paragonimus westermani
2. Fasciola hepatica
3. Clonorchis sinensis
4. Opisthorchis felineus
5. Heterophyes heterophyes
6. Metagonimus yokogawai
7. Echinostoma ilocanum
8. Fasciolopsis buski
9. Schistosoma mansoni
10. Schistosoma japonicum
11. Schistosoma haematobium

METHOD OF INFECTION

Eaten by man

Penetrates skin

Encysts in second intermediate host

Free-swimming cercaria

IN WATER

Scheme of multiplication in snail

Portal blood vessels

Intestine

Liver

Lung

Eggs in urine or feces

Eggs passed in feces

Egg eaten by snail or hatches, freeing a miracidium

First intermediate host

Penetrates soft parts of snail

Free-swimming miracidium
FLUKE LIFE CYCLE
Fasciola hepatica

SEXUAL GENERATION
Liver of sheep

1. Eggs
2. Zygote
3. Miracidium
4. Fertile eggs
5. Shed in feces
6. Adult

ASEXUAL GENERATION
Aquatic snail - Lymnaea sp.

1. Encysts on grass
2. Eaten by sheep
3. Developed egg
4. Larva penetrates snail
5. Sporocyst
6. Redia
7. Daughter redia
8. Cercaria
9. Metacercaria in cyst

V - may or not be present may have two of them none of one
FLUKE ANATOMY

Clonorchis

1. Oral sucker
2. Pharynx
3. Esophagus
4. Intestine
5. Nerve cord
6. Genital opening
7. Ventral sucker
8. Vas deferens
9. Uterus
10. Vas efferens
11. Vitelline gland
12. Vitelline duct
13. Shell gland
14. Oviduct
15. Ovary
16. Laurer’s canal
17. Seminal receptacle
18. Excretory duct
19. Excretory vesicle
20. Testis
Differential Characteristics of
IMPORTANT HUMAN ROUNDWORMS

Adults Living in Intestine

Actual Sizes of Females

Enterobius vermicularis
(Female)

Necator americanus

Enterobius vermicularis
(Male)

Ancylostoma duodenale

Seminal vesicles

Strongyloides stercoralis
(Parasitic female)

MOUTH WITH CUTTING PLATES

MOUTH WITH GLOBS

COPULATORY PUNA OF MALE
Ascaris lumbricoides Life Notes

• Average life span for adults ~ 3 years

• Eggs released /day/female > 200,000

• Eggs embryonate in soil in 2 to 3 weeks
Ascaris lumbricoides Life Cycle

- Infestation initiated when embryonated egg with SECOND stage larva swallowed
- Eggs hatch in small intestine
- Larvae penetrate intestinal wall
- Larvae enter the circulatory system
  - Larvae migrate to the heart
  - Larva moult – THIRD STAGE
- Larvae pumped via pulmonary artery to alveolar space of lungs
- Larvae migrate up respiratory tract to pharynx
Ascaris lumbricoides Life Cycle Continued

- Larvae swallowed and enter small intestine
  - Larvae moult – FOURTH STAGE
  - Larvae moult – MATURE ADULTS
- Adults attached to intestinal wall
  - Separate sexes
  - Mate
  - FEMALE RELEASES EGGS
Necator americanus

Filariform larvae penetrate skin

Larvae hatch in soil

Unembryonated eggs pass out in feces

Larvae migrate to lungs

Larvae penetrate alveoli

Larvae migrate up trachea, are swallowed

Adults mature in small intestine

PATHOLOGY

Normal

Anemia
Trichuris trichiura

Eggs are ingested

Larvae hatch in small intestine

Larvae migrate to colon

Adults mature in colon

Pathology

Eggs embryonate in soil

Unembryonated eggs pass out in feces

Adult female
Toxocara canis

Adults live in dog small intestine

Dog cats embryonated eggs, acquires adults

Eggs in feces
Embryonate in soil
Eggs ingested

Larvae penetrate small intestine
Larvae migrate to all organs

PATHOLOGY
Granuloma in retina

Liver

Larvae hatch in small intestine
Resistance to Treatment

• During sludge digestion, destruction of resistant parasite ova is primarily due to temperature and not a specific digestion process. Aerobic and anaerobic digestion inactivated parasite ova at temperatures greater than 131°F (55°C) in 2 hours and at 113°F (45°C) within days but only retarded ova development at temperatures less than 113°F (45°C). *Ascaris* and *Toxocara* ova were the most resistant.
Resistance to Treatment Continued

- Lime treatment of sludges did not produce consistent inactivation of *Ascaris*.
- The results of ammonification treatment were inconclusive, especially with *Ascaris*.
- Ultrasonication was effective in destroying *Toxocara* ova at 49 kHz during a 6 minute exposure, but was not effective in destroying *Ascaris* eggs.