HELMINTH OVA CONTROL IN WASTEWATER AND SLUDGE FOR AGRICULTURAL REUSE

B. E. Jimenez-Cisneros
Universidad Nacional Autónoma de México (UNAM), Mexico

Keywords: Agricultural reuse, helminth ova, pathogens, sludge, treatment, wastewater.

Contents

Summary

A new version of the WHO Guidelines for the Safe Use of Waste Water, Excreta and Greywater in Agriculture and Aquaculture has been released in 2006. These guidelines, among other things, establish criteria for the helminth ova content, considering them as one of the main targeted pollutants for developing countries. However, in spite of this breakthrough and the fact that helminth ova have been considered the main health risk

when wastewater is reused for irrigation or aquaculture, relatively little information exists on how to remove and inactivate helminth ova from wastewater and sludge and, consequently, there are few technological options for controlling them. Moreover, it is still common nowadays to find recommendations on how technology can be applied to solving this problem based on data related to the inactivation of thermo-tolerant coliforms, even though it is well known that these are not indicators of helminth ova behavior. Furthermore, treatment methods are unable to produce treated wastewater and sludge with the low helminth ova content required by such criteria due to the high initial content found in the developing world. Due to the great need to apply adequate control methods in developing countries to address helminthiasis problems, this paper presents useful information for environmental and sanitary engineers concerning: (a) the general characteristics of the helminth ova; (b) the common helminth ova genus found in wastewater and sludge around the world; (c) the reason why common water and sludge disinfection methods are not effective at inactivating helminth eggs; (d) the main removal and inactivation mechanisms, (e) the processes that in practice have effectively removed or inactivated helminth ova and (f) how its content is measured in wastewater and sludge.

1. Introduction

In several regions of the world, wastewater (treated or untreated) and sludge, are being used for agricultural works. In 1989, the World Health Organization (WHO) drew attention to diarrheic diseases caused by these practices and the presence of helminth ova. In agreement, WHO set guidelines for its safe reuse. In 1992, the US-EPA published biosolids and sludge criteria (part 503) defining the elimination of helminth ova as a key parameter for sludge revalorization in agriculture. In 2006, WHO once again released guidelines, this time for the safe use of wastewater, fecal material and sludge in agriculture and aquaculture with a recommendation on the helminth ova content to a value that for developing countries will imply using treatment methods with 1-3 log removal or inactivation efficiencies, for which there is almost no information available. In spite of the importance of helminth ova as waterborne vectors, throughout the years, little attention has been paid to them in terms of their characterization and control, in both wastewater and sludge. Helminth ova are still poorly known and understood in the water profession and are often thought to be similar to microorganisms (bacteria, viruses and protozoa) even though they behave very differently. This chapter reviews from a practical point of view: (a) general characteristics of helminth ova; (b) common helminth ova genus found in wastewater and sludge around the world; (c) the reason why common water and sludge disinfection methods are not effective at inactivating helminth eggs; (d) main removal and inactivation mechanisms, and, (e) processes that in practice have effectively removed or inactivated helminth ova. This consolidated information (until now spread across research and internal reports papers) addresses to water professionals dealing with wastewater and sludge problems in developing countries. Information should also encourage researchers to look for more useful information on helminth ova characteristics but as well on removal and inactivation methods.

2. General Information

2.1. Helminthiasis: A Common Disease

Globally there are 5 million people suffering helminthiasis, mainly in developing countries. Helminthiasis is particularly common in regions where poverty and poor sanitary conditions are dominant. Under these circumstances helminthiasis incident rates reach 90%. There are several kinds of helminthiasis, Ascariasis being the most common and endemic in Africa, Latin America and the Far East. 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. Around 1.5 million of these children will probably never bridge the growth deficit, even if treated. Helminthiasis is transmitted through: (a) the ingestion of polluted crops, (b) contact with polluted sludge, faeces or wastewater, and (c) the ingestion of polluted meat.

2.2. Helminths' Life Cycle

Helminthiasis infective agents are the eggs, not the worms. Worms cannot live either in wastewater or in sludge because they need a host. Therefore, part of the control strategy for helminthiasis is to remove the eggs from wastewater and later inactive them in the sludge produced from wastewater treatment. Helminths are pluri-cellular worms; they are not microbes although their eggs are microscopic. Helminths come in different types and sizes (from 1 mm to several m in length), with several life cycles and ideal living environments. Besides humans some of them have intermediary hosts (such as *Schistosoma* spp. that live temporarily in a snail). Helminths' life cycle is very complex and different from that of bacteria and protozoan, which are well-known microbes in the wastewater treatment field. The *Ascaris lumbricoide's* life cycle illustrates this complexity well. When a person ingests *Ascaris* eggs (1-10), they adhere to the duodenum where the larva leaves the shell, crossing the wall into the blood stream. Through the blood *Ascaris* travels to the heart, lungs and bronchus tubes where it breaks the walls remaining in the alveolus around 10 days. The larva then travels to the trachea from where it is ingested again returning to the intestine. Back in the intestine, *Ascaris* reaches its adult phase, and, if female, produces up to 27 million eggs. During, its migration, *Ascaris* provokes allergic reactions (fever, urticaria and asthma); it may also sometimes lodge in the kidney, bladder, appendix, pancreas or liver forming cysts that can only be removed through surgery. In the intestine, *Ascaris* produces abdominal pain, meteorism, nausea, vomiting, diarrhea and undernourishment. Helminthiasis diseases have different manifestations but in general they cause intestinal wall damage, hemorrhages, deficient blood coagulation and undernourishment. Helminthiasis can degenerate into cancer tumors.

2.3. Classification

There are three different types of helminths: (a) Plathelminths, or flat worms, (b) Nemathelminths, Nematodes or round worms, and (c) Annelids (see Figure 1). In the sanitary engineering field only the first two are of importance. A common characteristic of helminths is that they reproduce through eggs. The eggs of different helminths differ in shape and size (see Figure 2). As can be seen in Figure 1 it is improper to use the terms nematodes, *Ascaris* and helminths as synonyms, as frequently happens in the sanitary engineering literature. This misunderstanding comes from the fact that *Ascaris* (a nematode) is the most common helminth egg in wastewater and sludge (see Figure 3).

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.

Table 1: Survival time of different pathogens in soil and crops

Normally, eggs contained in wastewater are not infective. To be infective they need to develop larva, for which a certain temperature and moisture are required (26^{o}C and 1 month in laboratory conditions. Conditions usually found in soil or crops are suitable for the development of larvae in 10 days, hence the risk of using polluted wastewater or sludge in agricultural fields. According to information that is now several years old and obtained, using a much less sensitive helminth ova analytical technique than the one available nowadays, it was found that they live in water, soil and crops for several months, a period of time that it is much longer than the one for microorganisms (1-2 months in crops and many months in soil, see Table 1).

3. Helminth Ova in Wastewater and Sludge

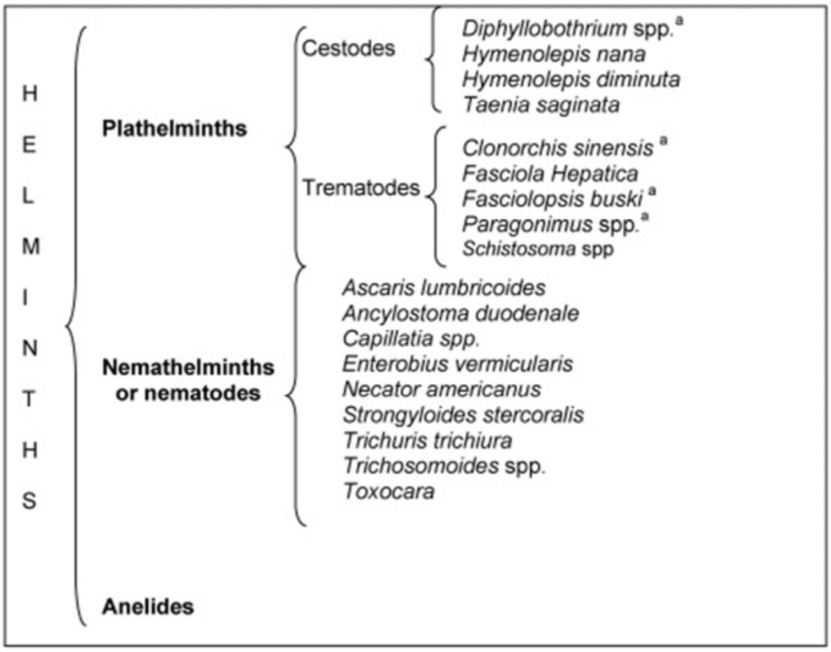
3.1. Type and Content

Due to differences in health and conditions according to the little literature available on the subject, helminth ova content in wastewater and sludge is very different (Table 2) in developed and developing countries. Moreover, the distribution genera presented vary from country to country, reflecting local health conditions. Different helminth ova genus reported as detected either in wastewater or sludge are mentioned in Figure 1, while a general distribution of genus, but not representative for all countries is presented in Figure 3.

Country/region	Municipal wastewater HO L^{-1}	Sludge HO g^{-1} TS
Developing countries	70-3000	70-735
Brazil	166–202	75
Egypt	No data	Mean: 67; Maximum: 735
Ghana	No data	76
Jordan	300	No data
Mexico	6–98 in cities	73-177

	Up to 330 in rural and peri-urban areas	
Morocco	840	No data
Ukraine	60	No data
France	9	5-7
Germany	No data	< 1
Great Britain	No data	< 6
United States	1-8	2-13

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



[a] Found only in wastewater and sludge from some regions of Asia.

Figure 1: Helminth classification and common genus found in wastewater and sludge.

3.2. Fecal Coliforms as Indicators

Fecal coliforms are the bacterial pollution indicators most extensively used, and it is frequently, and wrongly, assumed that they are indicators of any kind of biological pollution. Even though fecal coliforms are useful indicators of fecal pollution in developed countries, this is not the case in developing ones owing to the presence of a wide variety and larger quantities of microorganisms. This does not mean that fecal coliforms are not useful in developing countries, simply that care must be taken to select additional indicators for specific purposes, such as agriculture and aquaculture wastewater and sludge reuse, which is where helminth ova fit in, given that they are one of the main associated health risks displaying a much higher resistance to environmental conditions than viruses, bacteria and protozoa. Actually, in contrast to fecal coliforms, helminth ova cannot be inactivated with chlorine, UV light or ozone (in the latter case at least not with economical doses because >36 mg O_3 L^{-1} are needed with 1 hour contact time.

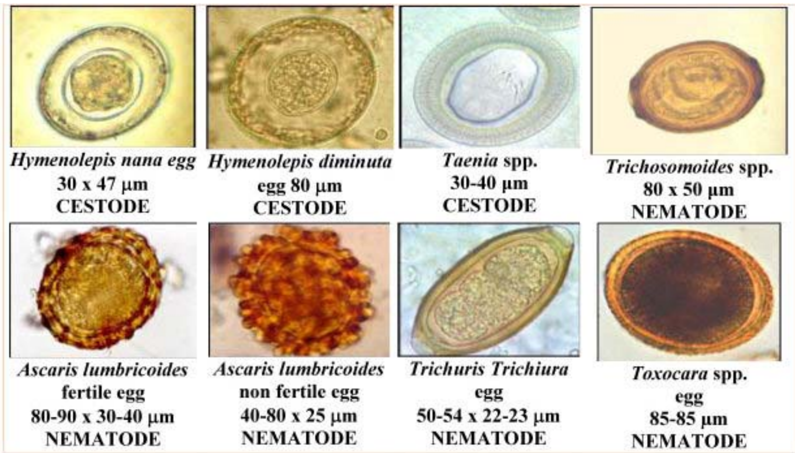


Figure 2: Helminth eggs observed in wastewater and sludge

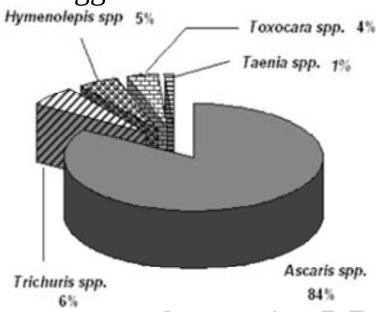


Figure 3: Genus found in wastewater

3.3. Helminth Ova Criteria

As shown in Table 2, not all wastewater and sludge contain significant amounts of helminth ova. For this reason they are not considered in all wastewater and sludge countries' norms as is the case of BOD or fecal coliforms, which are universal parameters. Based on epidemiological studies WHO has set a recommended limit of ≤ 1 HO L^{-1} for the irrigation of crops that are eaten uncooked for both restricted and unrestricted irrigations, but for drip irrigation of high growing crops (crops not growing down or on the soil), there is no recommendation. For fish culture with wastewater, the trematode eggs (*Schistosoma* spp., *Clonorchis sinensis* and *Fasciolopsis buski)* maximum content has been set as zero, as these worms multiply by tens of thousand producing millions of eggs in their first intermediate aquatic host (a snail) before infecting fish and humans.

In sludge or biosolids intended for agriculture, based on the value of ≤ 1 HO L^{-1} set for wastewater, some authors have calculated a limit criterion of 3 to 8 HO g^{-1} TS for sludge depending on its application rate. This value is much higher than the 0.25 HO g^{-1} TS set in the United States as standard or the 1 HO g^{-1} TS set as criteria by WHO (for fecal sludge). The US EPA value has been set based on the inactivation removal achieved by most of the available treatment technologies (with efficiencies of around 90%) to treat sludge with a maximum helminth ova content of 10 HO g^{-1} TS. Anyway, in practice, both, standard and criteria mean very high inactivation efficiencies (< 99%)

for sludge and fecal sludge (due to high initial content normally found in developing countries) not affordable in practice.

The US-EPA standard value was defined for biosolids Class A (sludge with no restriction on use), while for biosolids Class B there are no helminth ova limits, although sludge can be reused in agriculture with some restrictions. Unfortunately, for sludge with greater content than those reported for the USA, very few economical feasible options are available for inactivating helminth ova in sludge or fecal sludge with low content values. Not applying any limit as is done for class B in US-EPA would be dangerous for the revalorization of sludge in developing countries.

4. Helminth Ova Characteristics

An important characteristic of helminth ova is that they are covered by 3-4 layers. The 1-2 outer layers are formed with mucopolysacharides and proteins. The middle layers consist of chitinous and serve to give structure and mechanical resistance to the eggs.

Finally, the inner layer is composed of lipids and proteins and is useful to protect eggs from desiccation, strong acid and bases, oxidants and reductive agents as well as detergent and proteolytic compounds. Thus the combination of all these layers is responsible for making eggs very resistant to several environmental conditions.

Helminth ova of concern in the sanitary field measure between 20 and 80 μm with a density of 1.06-1.15 and are gelatinous which makes them very sticky. All these properties determine helminth ova's behavior during wastewater and sludge treatment. First, it is very difficult to inactivate them unless the temperature is raised above 40^{o}C or moisture is reduced to below 5% (TS > 95%.

But details about the contact time under these conditions and other related environmental factors are generally not well-defined for every type of helminth ova genus or for high helminth ova content. Only for *Ascaris* has a contact time of 10-20 days at temperatures above 40^{o}C been reported.

In wastewater treatment, the inactivation conditions mentioned can hardly be achieved while in sludge treatment they are feasible. Thus, helminth ova are normally removed from wastewater and inactivated in sludge.

5. Helminth Ova Removal from Wastewater

Basically, to remove helminth ova from wastewater it suffices to realize that they are in fact particles forming a fraction of the suspended solids. This is why the helminth ova content is related to the total suspended solids content (TSS) in wastewater-specifically, to the amount of particles measuring 20-80 μm (Figure 4).

As helminth ova are particles, mechanisms used to remove suspended solids are also useful removing helminth ova from wastewater. These mechanisms are sedimentation, filtration and coagulation-flocculation.

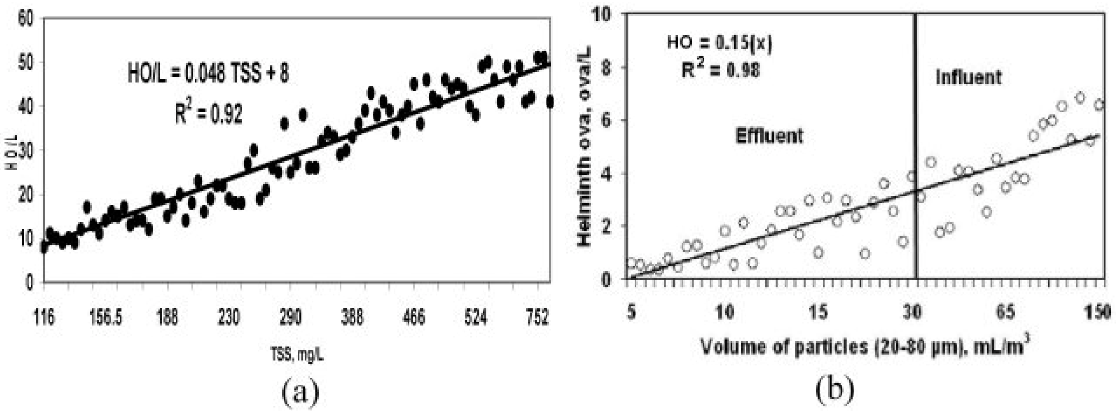


Figure 4: Correlation between helminth ova content in Mexico City's wastewater and (a) the TSS content and (b) the 20-80µm particles content

-
-
-

Bibliography

Aguilar P., Jiménez B., Maya C., Orta T. and Luna V. (2006) Disinfection of sludge with high pathogenic content using silver and other compounds. *Water Science and Technology*. 5(54): 179-187. [This paper contains data on helminth ova and other pathogens disinfection in sludge]

Andreoli C., Ferreira A., Teles C., Cherubini C., Bernet P., Favarin F., Castro L. (2000) Operation of different options to disinfect and dry sludge anaerobically digested. I Seminário Nacional De Microbiologia Aplicada Ao Saneamento. Anais.Vitória, In Portuguese. [Decribes helminth ova inactivation in treated sludge in Brazil]

Atlas of Medical Parasitology (2000) Infectious Disease Unita. Tropical and Parasitology Service, Amadeo di Savoia Hospital. The editor Editor Pietro Caramello MD. http://www.cdfound.to.it/html/manager.htm [Contains photographs of different human pathogens]

Austin A. and Duncker L. (2002) Urine-diversion ecological sanitation systems in South Africa. CSIR, Pretoria. [Describes operation of Ecosan systems and its application in South Africa]

Ayres R. (1989) A Practical Guide for the Enumeration of Intestinal Helminths in Raw Wastewater and Effluent from Stabilization Ponds. Leeds University Department of Civil Engineering. [It is an analytical method to enumerate helminth ova in wastewater]

Ayres R., Alabaster G., Mara D. and Lee D. (1992) A Design Equation for Human Intestinal Nematode Egg Removal In Waste Stabilization Ponds. *Water Research* 26(6): 863-866. [From data gathered in field conditions this paper develops an equation to calculate helminth ova removal in stabilization ponds]

Barrios J., Jiménez B. and Maya C. (2004) Treatment of sludge with Peracetic Acid To reduce the Microbial Content, *Journal of Residuals Science and Technology* 1(1): 69-74. [The application of peracetic acid to inactivate helminth ova, protozoan and pathogenic bacteria is described]

Bratton, R. and Nesse, R. (1993) Ascariasis: an infection to watch for in immigrants. *Postgraduate Medicine* 93:171–178. [This paper presents data on the increment on helminthiasis morbidity in USA caused by immigration]

Brownell S. A. and Nelson K. L. (2006) Inactivation of single-celled *Ascaris suum* eggs by low-pressure UV radiation. *Appl. Environ. Microbiol*. 72(3):2178-2184. [Results showing the inefficacy of UV-light to inactive helminth ova are presented]

Cairncross S. and Feachem R. (1993) Environmental Health Engineering in the Tropics. John Wiley and Sons, Chichester, UK- [This book contains data on public health for developing countries considering engineering techniques to stop the dissemination of diseases]

Carrington E., Pike E., Autry D. and Morris R. (1991) Destruction of faecal bacteria, enteroviruses and ova of parasites in wastewater sludge by aerobic thermophilic and anaerobic mesophilic digestion. *Water Science and Technology* 24(2): 377-380. [Results of the application and limitations of anaerobic thermophilic digestion to disinfect sludge are discussed]

Camp Dresser and McKee (1993) As-Samra wastewater stabilization ponds emergency short-term improvement system. Report for the Hashemite Kingdom of Jordan, Ministry of Water and Irrigation, Cambridge, Massachusetts. [Describes performances and limitations of a stabilization pond system to treat wastewater, operational problems are particularly discussed]

Capizzi S. and Schwartzbrod J. (1998) Helminth egg concentration in wastewater: Influence of rainwater. *Water Science and. Technology* 38(12):77-82. [Data of the helminth ova content in wastewater from developed countries is presented]

Capizzi B. and Schwartzbrod J. (2001) Irradiation of Ascaris ova in sludge using an electron beam accelerator. *Water Research* 35(9):2256-2260. [The inactivation of *Ascaris suum* using a high efficiency disinfection method is presented]

Chavez A., Jimenez B. and Maya C. (2004) Particle size distribution as a useful tool for microbial detection *Water Science and Technology* 50(2):179-186. [The use of a particle counter as a way to indirect measure the helminth ova content in wastewater is presented]

De Victorica, J. and Galvan, M. (2003) Preliminary testing of a rapid coupled methodology for quantization/viability determination of helminth eggs in raw and treated wastewater. *Water Research* 37(6):1278-87. [The use of a colorant to determine helminth ova viability in some minutes is presented as an alternative to the incubation method]

Duqqah M. (2002) Treated sewage water use in irrigated agriculture. Theoretical design of farming systems in Seil Al Zarqa and the Middle Jordan Valley in Jordan. PhD Thesis, Wageningen University, The Netherlands. [Data on the pathogenic content on wastewater is presented as well as the design method to treat it properly for agricultural irrigation]

Ellis K., Rodrigues P. and Gómez C. (1993) Parasite ova and cysts in waste stabilization ponds. *Water Research* 27(9): 1455-1460. [The influent and effluent pathogenic content in a stabilization pond is analyzed considering the operating conditions]

Faust E. C., Sawitz W., Tobie J., Odem V. and Peres C. (1939) Comparative efficiency of various techniques for the diagnosis of protozoa and helminths in faeces. *Journal Parasitology* 25: 241-262. [Different analytical techniques to enumerate helminth ova content in feces are presented]

Feachem R., Bradley D., Garelick H. and Mara D. (1983) Sanitation and disease: Health aspects of excreta and wastewater management. John Wiley and Sons, New York, NY. [This book contains useful but in some cases outdated data on public health for environmental engineers]

Galván M., Gutierrez A. L. and De Victorica J. (1996) Efficiency of rapid quantitative procedures adapted for the analysis of helminth eggs in irrigation water. Proceedings of the IAWQ Symposium on Health Related Water Microbiology. Malloca, Spain, October pp. 91-96. [The use of a colorant to determine helminth ova viability in some minutes is presented as an alternative to the incubation method]

Gantzer C., Gaspard P., Gálvez L., Huyard A., Dumouthier N. and Schwartzbrod J. (2001) Monitoring of bacterial and parasitological contamination during various treatment of sludge. *Water Research* 35(16): 3763-3770. [This papers compare the pathogenic content in sludge treated using different methods and technologies]

Harleman D. and Murcott S. (1999) The Role of Physical Chemical Wastewater Treatment in Mega cities of the Developing World. *Water Science and Technology* 40(4-5): 75-80. [The application of a Chemical enhanced primary treatment using coagulants is discussed as a way to properly treat wastewater form megalopolis that reuse their water for agricultural irrigation or discharge it into the ocean]

Hays B. (1977) Potential for parasitic disease transmission with land application of sewage plant effluents and sludge. *Water Research* 11(7): 583-595 [This paper analyses the pathway used by helminth ova to infect humans as a result of improper sanitation practices. It also describes types and content of helminth ova in sludge]

Hespanhol I. (2002) Saúde Pública e Reúso Agrícola de Esgotos e Biosólidos (Public Health and Use of Wastewater and Sludge in Agriculture), in Reúso de Água (Water Reuse), 75-87 pp, Marduzo P.C.S. and Santis H.F., eds., 430 pp, Editora Manole, São Paulo, In Portuguese. [This paper develops guidelines for sludge disposal based on the results of health risk studies developed for the use of wastewater to irrigate by WHO]

Huntington R. and Crook J. (1993) Technological and environmental health aspects of wastewater reuse for Irrigation in Egypt and Israel WASH Field report No. 418 Report prepared for US Agency of International Development, Near East Bureau, and Washington D.C. [The paper analyses useful technologies to control the high pathogenic content in wastewater from two countries]

Jimenez B. and Chavez-Mejia A. (1997) Treatment of Mexico City Wastewater for Irrigation Purposes. *Environmental Technology* 18:721-730. [The paper compares different technology to efficient treat wastewater with high helminth ova content at a low cost. It also presents the selection of the operating conditions for an APT system]

Jiménez B., Maya C. and Salgado G. (2001) The Elimination of Helminth Ova, Fecal Coliforms, Salmonella and Protozoan Cysts by Various Physicochemical Processes in Wastewater and Sludge. *Water Science and Technology* 43(12): 179-182. [The removal of different pathogens at different stages of treatment processes is presented for a wastewater having initially a high content and a wide variety of them]

Jimenez B. and Chavez A. (2002) Low Cost Technology for Reliable Use of Mexico City’s Wastewater for Agricultural Irrigation. *Water Science and Technology* 9(1-2): 95-108. [Operating conditions to remove helminth ova and inactivate bacteria while maintaining nutrients in wastewater is discussed for an APT system]

Jimenez B. (2003) Health Risks in Aquifer Recharge with Recycle Water in State-of-the-Art Report Health Risk in Aquifer Recharge Using Reclaimed Water. Aertgeerts R: and Angelakis A. Editors. WHO Regional Office for Europe. [The chapter describes the type, content and responses to environmental conditions of different microoganisms that are relevant to the use of wastewater to recharge aquifers that are intended for human consumption]

Jimenez B., Austin A., Cloete E. and Phasha C. (2006) Using Ecosan sludge for crop production. *Water Science and Technology*. **5**(54): 169-1976 [The microbial effects of applying sludge coming from an ecosan on food crops are presented]

Jiménez B. and Wang L. (2006) Sludge Treatment and Management, Chapter 10, pp 237-292 in Municipal Wastewater Management in Developing Countries: Principles and Engineering, Ujang Z. and Henze M. Editors. International Water Association Publishing. London, U.K. [Principles, treatment methods and legislation to treat sludge for developing countries are described on this chapter]

Jiménez B., Martínez M. and Vaca M. (2006) Alum Recovery and Sludge Stabilization with Sulfuric Acid in an APT Wastewater Treatment Plant. *Journal of Residuals and Technology* 3(3): 169-176. [The effect of recovering alum from a wastewater sludge on the sludge mass reduction and on the inactivation of helminth ova and bacteria using and acidic method is presented]

Juanicó M. and Milstein A. (2004) Semi-intensive treatment plants for wastewater reuse in irrigation. *Water Science and Technology* 50(2): 55-60. [The use of reservoirs as batch systems to improve wastewater quality for agricultural reuse is analyzed]

Keller R., Passamani F., Cassini S. and Goncalves F. (2004) Disinfection of sludge using lime stabilization and pasteurization in a small wastewater treatment plant. *Water Science and Technology* 50(1): 13-17. [The application of lime post-stabilization in sludge produced in small wastewater treatment plants is presented considering operating conditions and efficiencies]

Kunert J. (1992) On the Mechanism of Penetration of Ovicidal Fungi Through Egg-Shell of Parasitic Nematodes. Decomposition of Chitinous and Ascaroside Layers. *Paratologica* 39:61-66. [The composition of the nematodes eggs is presented, explaining why it is important to protect them]

Krugel S., Nemeth L. and Peddie C. (1998) Extending Thermophilic Anaerobic Digestion for Producing Class A Biosolids at the Greater Vancouver Regional Districts Annacis Island Wastewater Treatment Plant. *Water Science and Technology* 38(8-9):409-416. [The use of thermophilic anaerobic digestion to disinfect sludge with a low pathogen content is presented]

Landa H., Capella A. and Jiménez B. (1997) Particle size distribution in an effluent from an advanced primary treatment and its removal during filtration. *Water Science and Technology* 36(4):159-165. [The use of a sand filter to remove suspended solids and pathogens is presented from a laboratory study]

Lynch J., Pfaffin J. Pecker C., Cárdenas R., Cunningham S., Bozzone R. and Borg S. (1984) Method for the treatment of wastewater sludge. Patent No. 4'500,428, E.U. [This patent describes the use of acids to inactive microorganisms and pathogens]

Mara D. (2004) Domestic Wastewater Treatment in Developing Countries Ed. Earth Scan, London [This book contains principles, data and methodologies to proper treat wastewater in developing countries]

Maya C., Jiménez B. and Schwartzbord J. (2006) Comparison of Techniques for the Detection of Helminth Ova in drinking water and Wastewater. *Water Environment Research* 78(2): 118-124. [The paper compares four different and common analytical techniques used to enumerate helminth ova content in wastewater]

Méndez J., Jiménez B. and Barrios J. (2002) Improved Alkaline Stabilization of Municipal Wastewater Sludge. *Water Science and Technology* 46(10): 139-146. [The application of lime post-stabilization to produce class B biosolids from a sludge with high pathogenic content is presented]

Nelson K, J-Cisneros B., Tchobanoglous G. and Darby J. (2004) Sludge accumulation, characteristics, and pathogen inactivation in four primary waste stabilization ponds in central Mexico. *Water Research* 38(1):111-127. [In sludge coming from different stabilizations ponds having different time under operation, the content of total and viable helminth ova has been measured]

Oropeza M., Castro P., Ortega S. and Chabirol N. (2000) Mesofilic and thermofilic anerobic digestion of biological and physicochemical sludge. XII National Congress of the Mexican Federation of Sanitary Engineering and Environmental Science 1:789-803. Morelia, México (In Spanish). [Efficiencies and problems to operate a thermophilic anaerobic process to inactivate helminth ova are presented]

Paulino R., Castro E. and Thomaz-Soccol V. (2001) Helminth eggs and protozoan cysts in sludge obtained by anaerobic digestion process. *Revista de la Socciedad Brasileña de Medicina Tropical* 34(5): 421-428. [The helminth ova removal in an anaerobic process is measured in field conditions]

Rivera F., Warren A., Ramirez E., Decamp O., Bonilla P., Gallegos E., Calderón A. and Sánchez J. (1995) Removal of pathogens from wastewater by the root zone method (RZM). *Water Science and Technology* 32(3): 211-218. [Pathogen removal at different conditions is measured in a wetland from a tropical area]

Rojas-Valencia N., Orta M., Vaca M. and Franco V. (2004) Ozonation by-products issued from the destruction of microorganisms present in wastewaters treated for reuse. *Water Science and Technology* 50(2): 187–193. [The application of ozone to inactivate helminth ova is studied using different operating conditions]

Strauss M. and Blumenthal U. (1990) Use of Human wastes in agriculture and aquaculture. IRCWD Report No 08/90, Duebenforf, Switzerland. [Using data from several countries the health effect of using human wastes to fertilize soil are analyzed]

Strauss M., Drescher S., Zurbrügg CH. and Montangero A. (2003) Co-composting of Fecal Sludge and Municipal Organic Waste. A Literature and State-of-Knowledge Review, Swiss Federal Institute of Environmental Science and Technology (EAWAG) and IMWI [The methodology to produce compost from municipal waste and fecal sludge is presented, considering efficiencies in inactivating pathogens]

Silva N., Chan M. and Bundy A. (1997) Morbidity and mortality due to Ascariasis: re-estimation and sensitivity analysis of global numbers at risk. *Tropical Medicine and International Health* 2(6): 19-28. [Number on the extent of helminths diseases are presented]

Stott R., Jenkins T., Baghat M., and Shalaby I. (1999) Capacity of constructed wetlands to remove parasite eggs from wastewater in Egypt. *Water Science and Technology* 40(3): 117-123. [The performance of wetlands to remove pathogens is measured in field conditions]

Theis J. Bolton V. and Storm Davis R. (1978) Helminth ova in soil and sludge from twelve U.S. urban areas. *Journal of the Water Pollution Control Federation* 50: 2485-2493. [The survival of helminth ova in sludge and soil is analyzed]

US-EPA. (1992) Control of Pathogens and Vector Attraction in Sewage Sludge EPA/625/R-92-004. Washington, D.C. [The methods to apply the USEPA sludge legislations are presented in an affordable way for engineers]

WHARTON D. (19080). Nematode Egg-Shells. *Parasitology*. 81:447-463. [The composition of shells of a specific kind of helminths is analyzed]

WHO (1989) Health Guidelines for the use of Wastewater in Agriculture and Aquaculture, Technical Report Series No 778, World Health Organization, Geneva. [Guidelines to use wastewater and excreta to fertilize soils intended for agriculture or ponds used for aquaculture are presented]

WPCF (1988) Sludge Conditioning, Manual of Practice FD-14. Water Pollution Control Federation, United States of America. [Design and operating conditions to treat and manage sludge are presented]

WHO (2006) Guidelines for the Safe use of Wastewater, Excreta and Greywater in Agriculture and Aquaculture. Vol.1, 2, 3 and 4. World Health Organization, Ed. Paris, France. [Guidelines to use wastewater and excreta to fertilize soils intended for agriculture or ponds used for aquaculture are presented]

Xanthoulis D. and Strauss M. (2005) A tentative guideline for a permissible concentration of viable eggs in sludge. Paper presented at the Expert meeting to discuss the Wastewater and Fecal Sludge for reuse in agriculture and aquaculture, 2005. [Based on WHO studies assessing the health risks of using wastewater for irrigation this paper develops guidelines for the safe content in sludge used as fertilizer]

Von Sperling C., Chernicharo A., Soares and Zerbini A. (2002) Coliform and helminth eggs removal in a combined UASB reactor – baffled pond system in Brazil: performance evaluation and mathematical modelling. *Water Science and Technology* 45(10): 237–242. [The limitation of using a UASB reactor to produce a reliable and high quality microbial effluent is discussed. The use of stabilization ponds to improve UASB performance is presented]

UN (2003) Water for People Water for Life, The United Nations World Water Development Report. Barcelona: UNESCO. [Data from all over the world on the status of water quantity, quality, management, policy and infrastructure is presented]

Biographical Sketch

Blanca Jimenez was born in Mexico City, where she obtained a *Bachelor's degree in Environmental Engineering.* She has Masters and a PhD degree in Wastewater Treatment from the Institut National de Sciences Appliquées, Toulouse, France. She works since 1985 at the National Autonomous University (UNAM) where she is Senior Researcher. In 1992 she founded the graduate program in Environmental Engineering in the state of Morelos and in 1994 launched the prestigious UNAM Group of Wastewater Treatment and Reuse.

Dr Jiménez has published more than 180 international papers and has 4 patents. She has published the book: "Environmental Pollution in Mexico. Causes, Effects and Technology": She has been responsible for more than 117 research projects for several public and private institutions. Due to her professional reputation Dr. Jiménez has been invited to lecture more than 100 conferences in several countries. She has been awarded several prizes like the National Ecology Award (as best academic in the environmental) 2006, the Environment and Ecology Award "Miguel Alemán Valdés" (2001), the Award for Scientific Research in the area of Technology Research, granted by the Mexican Academy of Sciences, (1997) and the Ciba Award for Technological Innovation in Ecology (1993). She is the chairperson of the Water Reuse Specialty Group in the International Water Association. She was President of the Mexican Association of Environmental Engineers, the Mexican Federation of Sanitary Engineering and Environmental Sciences (the oldest environmental professionals association in the country), and belongs to the Executive Committee of the International Water Association.