PUBLIC HEALTH ASPECTS OF ON-SITE SANITATION

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Summary

The disastrous impact of improper sanitation practices on world populations has made us realize the necessity of according due importance to public health and sanitation aspects. The importance of proper sanitation and the need to ensure complete pathogen destruction in the water and wastewater treatment process cannot be overstressed. Prevention of health hazards usually associated with improper sanitation necessitates a better understanding of the infection-causing pathogens themselves. A host of information is now available on the transmission of various excreted infections. It is now known that the probability that the excreted pathogens from one host will form the infective dose for another is dependent on “latency”, “persistence”, and “multiplicity” of the pathogens involved. The four groups of pathogens that are predominantly responsible for the cause of diseases in humans are bacteria, viruses, protozoa, and helminths. There is a better understanding of the mode of transmission of these pathogens and their ability to survive in the different environments. Various methods to ensure reliable detection of these pathogens are now in place. These methods of detection prove invaluable in designing treatment schemes to ensure their destruction. There are several on-site sanitation systems like pit latrines, composting toilets, cartage systems, aquaprivies and septic tanks. All these systems do have their share of health implications, and care has to be taken to ensure that these systems are used and operated in a way that would minimize these health hazards.

1. Introduction

A World Health Organization (WHO) survey in 1975 showed that 75% of urban dwellings in developing countries did not have sewers for the disposal of excreta and 25% had no disposal system of any kind. In rural areas of the developing countries, 85% of the dwellings did not have proper excreta disposal facility. While in the wealthy and industrialized countries, where most people have the requisite excreta disposal facilities, the treatment and disposal of these wastes pose considerable problems.

The first world pandemic of Asiatic cholera began in Bengal, India in 1817 and reached Western Europe in 1831 and North America a year later. The extremely fatal impact of the disease on world populations inspired research into the cause of the epidemic by William Farr and John Snow, universally acknowledged as the founders of epidemiology. They brought attention to the relationship between polluted water and disease in their studies. Around the same time, Edwin Chadwick was campaigning for increased provision of water, adequate in quality and quantity, to the growing world populations. The need to integrate water supply improvements and sanitation was increasingly being felt.

Soon afterwards it became known that water-related diseases caused by pathogens included typhoid, filariasis and malaria. The disease-causing pathogens in human excreta (feces and urine) travel from the anus of a person to the mouth of another in a variety of ways—sometimes on dirty fingers, on food and utensils, through water or by any other route—that allows infected excreta to be ingested.

Public health and sanitation aspects are increasingly assuming central importance in the design and implementation of excreta treatment and disposal projects in all countries. The importance of proper sanitation, coupled with effective treatment methods to ensure complete pathogen destruction in excreta prior to disposal and reuse, is strongly being felt.

Design of an effective excreta disposal system needs, among other things, an adequate understanding of the relationship between excreta and health. There are two reasons that necessitate the importance of studying the impact of sanitation on public health. First, information on health impact helps to allocate resources between projects and other measures such as immunization programs designed to improve public health. Data on health impact also enables review on resource allocation in the water supply, sanitation and hygiene education sectors. Secondly, knowledge of health impact assists with the design of projects, and their impact on health at a given cost can be optimized.

2. Factors Affecting Transmission of Diseases

The probability of an excreted infection being transmitted depends on various factors. An infective dose has to pass from the excreta of a person, vector or a reservoir of infection to the mouth or any other entryway of a susceptible person. Spread will depend upon the numbers of pathogens excreted, upon how these numbers change during the particular transmission route, and upon the dose required to infect a new individual. The probability that, for a given transmission route, the excreted pathogens from one host will form the infective dose for another is dependent on three factors—latency, persistence, and multiplicity.

2.6. Excreted Load

Excreted load is the concentration of pathogens passed by an infected person and it varies widely from infection to infection. A person with a worm infection may pass on only a few eggs per gram of feces, whereas a person with cholera may excrete 10^6 vibrios per gram of feces.

2.7. Infective Dose

Infective dose is the concentration of pathogens that has to enter a healthy person in order to cause infection. The infective dose would naturally vary among different people, depending upon their susceptibility to infection. The assessment of health risk can be calculated from the excreted load, the median infective dose (ID_{50}) of particular organisms and the efficiency of the excreta treatment processes in activating pathogens. Bacterial infections generally have a medium or high ID_{50} ($\geq 10^4$). Excreted viruses have low ID_{50} ($<10^2$) and in helminthic infections, a single egg or larva can infect if ingested.

The probability that the excreted load of an infected person will form the infective dose of another person will depend on factors like latency, persistence and multiplication (Figure 1).

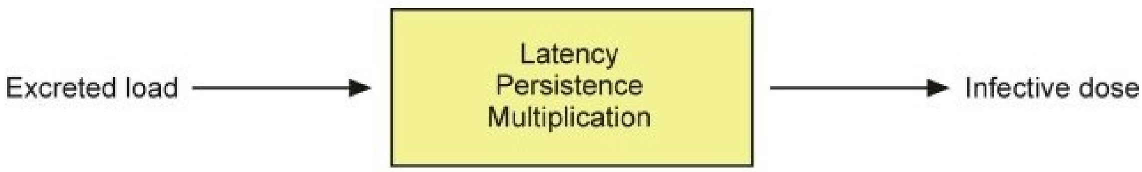

Figure 1. Factors affecting the transmission of an infective dose (source: *World Bank Studies in Water Supply and Sanitation, 3*)

2.8. Latency

Latency is the time period between the excretion of a pathogen and its becoming infective to a new host. Some organisms, including all viruses, bacteria and protozoa have no latency period and are immediately infectious in raw excreta. The requirements for the safe disposal of these excreta containing these organisms which have no latency period have to be very stringent. However, most of the helminthic infections have considerably long latency periods. Latency would affect the choice of excreta disposal systems.

2.9. Persistence

Persistence is a measure of the capability of the pathogens to stay alive outside the human body and subsequent to being excreted in the feces. It is the single property most indicative of the fecal hazard, as a very persistent organism will create a risk throughout most treatment processes and during reuse of the excreta. More persistent pathogens, thus, have a greater chance of generating new cases of disease, and hence need to be inactivated through elaborate treatment processes. Pathogens with low persistence can be expected to pose less of a concern because they cannot stay alive throughout the length of the treatment process of the sewage works.

While it is relatively easy to measure the persistence of pathogenic organisms by laboratory methods, to interpret the results obtained, it is necessary to know the quantity of pathogens being excreted in the feces and the infective doses for humans. The quantity of pathogens in the feces is fairly easy to measure but the calculation of infective doses for humans is extremely difficult.

2.10. Multiplication

Pathogens, originally in low numbers, can multiply under favorable conditions in the environment to produce a potentially infective dose. Bacteria may multiply on a favored substrate, while excreted viruses and protozoa do not multiply outside their hosts. Among helminths transmitted by excreta, all trematodes infecting humans undergo multiplication in aquatic snails.

3. Pathogens in Excreta

The four groups of pathogens found in excreta that are predominantly responsible for the cause of diseases in humans are:

(i) bacteria
(ii) viruses
(ii) protozoa
(iii) helminths.

3.5. Bacteria

The feces of a healthy individual contain large numbers of bacterial populations of many species. The species of bacteria found in the excreta, and the relative numbers of different species, will vary among different communities. Not all bacteria found in the excreta are pathogenic. Table 1 contains a list of pathogenic bacteria and the diseases caused by them.

Bacterium	Disease	Reservoir
Campylobacter fetus spp. *jejuni*	Diarrhea	Animals and human
Pathogenic *Escherichia Coli*[a]	Diarrhea	Human
Salmonella *S. typhi* *S. paratyphi* Other Salmonellae	 Typhoid fever Paratyphoid fever Food poisoning and other salmonelloses	 Human Human Animals and human

Shigella spp.	Bacillary dysentry	Human
Vibrio *V. cholerae* Other vibrios	 Cholera Diarrhea	 Human Human
Yersinia enterocolitica	Diarrhea and septicemia	Animals and human

[a] includes enterotoxigenic, enteroinvasive, and enteropathogenic *E. coli*

Table 1. Bacteria excreted in feces (source: World Bank Studies in Water Supply and Sanitation, 3)

Bacteria usually enter a new host by ingestion (in water, on food, on fingers, in dirt), but some may also enter through the lungs (by inhalation of aerosol droplets) or through the eye (rubbing the eye with fecally contaminated fingers). At some time during the course of an infection, large numbers of bacteria will be passed in the feces, thus allowing the spread of infection to new hosts.

Because of the fact that bacteria are ubiquitous and numerous in the feces of healthy people, they have been widely used as indicators of fecal pollution. The most widely used indicator is the fecal coliform (*Escherichia coli*), which is the main constituent of the enterobacteria group. The use of indicator organisms in the determination of fecal pollution is discussed in detail in a later section.

3.6. Viruses

Humans are known to excrete well over 100 different viruses. Several viruses are yet to be characterized and new viruses are constantly being discovered. Most viruses infect the intestinal tract and are excreted in the feces, whereupon they infect other healthy human hosts by ingestion or inhalation or any other mechanism previously described.

One gram of human feces may contain 10^9 infectious virus particles, regardless of whether the individual is experiencing any discernible illness or not. Concentrations of 10^5 infectious particles per liter of raw sewage have been reported in literature. Viruses cannot multiply outside a cell host, but may survive for many weeks, especially in cool environments (<15 °C).

The enteroviruses are a large group of viruses (polioviruses are the most important) causing a wide variety of diseases. The Hepatitis A virus causes infectious hepatitis and occurs endemically in all parts of the world. It is excreted in the feces and infection may lead to jaundice, especially in children. Rotavirus has been isolated in stools of children with diarrhea from developing and developed countries alike.

It is arguably more universally distributed than the Hepatitis A virus. The adenoviruses have been associated with respiratory disease in children. Reoviruses have been isolated from a large range of animal species, but there is not enough information about the diseases or symptoms caused by them. A classification of the most significant viruses and the diseases caused by them is presented in Table 2.

Virus	Disease	Reservoir
Adenoviruses	Numerous conditions	Human
Enteroviruses Polioviruses Echoviruses Coxsackie viruses	 Poliomyelitis, paralysis and other conditions Numerous conditions Numerous conditions	 Human Human Human
Hepatitis A virus	Infectious hepatitis	Human
Reoviruses	Numerous conditions	Human and animals
Rotaviruses, Norwalk agent and other viruses	Diarrhea	Probably human

Table 2. Viruses excreted in feces (source: World Bank Studies in Water Supply and Sanitation, 3)

3.7. Protozoa

Many species of disease-causing protozoa (Table 3) can infect humans, most of which are harbored in the intestinal tracts of human beings and other animals. Infective worms of these protozoa are often passed as cysts in the feces and their ingestion causes infection. Of the human intestinal protozoa, three are considered pathogenic: *Giardia lamblia*, *Balantidum coli*, and *Entamoeba histolytica*. Amebiasis is a term used to describe an infection by any of the ameba, chiefly *Entamoeba histolytica.* Giardiasis is an infection of the small intestine of humans by the flagellate protozoon *Giardia lamblia.* Amebiases and giardiasis are major public health concerns in many developed and developing countries. Balantidiasis, an infection of the large intestine caused by Balantidum coli, is relatively rare.

Protozoa	Disease	Reservoir
Balantidum coli	Diarrhea, dysentry and colonic ulceration	Human and animals (mainly pigs and rats)
Entamoeba histolytica	Colonic ulceration, amebic dysentery, and liver abscess	Human
Giardia lamblia	Diarrhea and malabsorption	Human and animals

Table 3. Protozoa excreted in feces (source: World Bank Studies in Water Supply and Sanitation, 3)

3.8. Helminths

Table 4 has a list of the disease-causing helminths in feces and their transmission routes. Only *Schistosoma haematobium* is found in the urine, while the others are excreted in the feces. Helminths, with the exception of *Strongyloides* do not multiply within the human host, and this is of significance in understanding their mode of transmission and the ways they cause disease.

Helminthic diseases differ from other viral, bacterial and protozoal diseases in an interesting way. Viruses, bacteria and protozoa multiply within the host, and in diseases caused by them, the severity of the infection cannot be easily related to the infecting dose of organisms. On the other hand, with helminthic infections, the number of parasitic worms or helminths within the infected person would greatly determine the severity of the infection, which generally increases with increasing worm count in an infected person.

Helminth	Disease	Transmission route
Ancylostoma duodenate	Hookworm infection	Human-soil-human
Ascaris lumbricoides	Ascariasis	Human-soil-human
Clonorchis sinensis	Clonorchiasis	Human/animal - A.S.[1] - fish - human
Diphyllobothrium latum	Diphyllobothriasis	Human/animal - copepod - fish - human
Enterobius vermicularis	Enterobiasis	Human - human
Fasciola hepatica	Fascioliasis	Sheep - A.S.[1] - A.V.[2] - human
Fasciolopsis buski	Fasciolopsiasis	Human/pig - A.S.[1] - A.V.[2] - human
Gastrodiscoides hominis	Gastrodiscoidiasis	Pig - A.S.[1] - A.V.[2] - human
Heterophyes heterophyes	Heterophyiasis	Dog/cat - BWS[3] - BWF[4] - human
Hymenolepis nana	Hymenolepiasis	Human/rodent - human
Metagonimus yokogawai	Metagonimiasis	Dog/cat - A.S.[1] - freshwater fish - human
Necator americanus	Hookworm infection	Human - soil - human
Opisthorchis felineus *O. viverrini*	Opisthorchiasis Opisthorchiasis	Cat/human - A.S.[1] - fish - human
Paragonimus westermani	Paragonimiasis	Human/animal - A.S.[1] - crab/crayfish - human
Schistosoma haematobium *S. Japonicum* *S. mansoni*	Schistosomiasis; bilharziasis Schistosomiasis Schistosomiasis	Human - A.S.[1] - human Animals/human - snail - human Human - A.S.[1] - human
Strongyloides stercoralis	Strongyloidiasis	Human - human
Taenia saginata *T. Solium*	Taeniasis Taeniasis	Human - cow - human Human - pig (or human) - human
Trichuris trichuria	Trichuriasis	Human - soil - human

[1] Aquatic snail; [2] Aquatic vegetation; [3] Brackish water snail; [4] Brackish water fish

Table 4. Helminths excreted in feces (source: World Bank Studies in Water Supply and Sanitation, 3)

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Biographical Sketches

T. Viraraghavan graduated in civil engineering from the University of Madras in 1955 from the College of Engineering, Guindy, Madras, India. He worked for the Government of Tamil Nadu (Madras) for 10 years as Assistant Public Health Engineer and later for 5 years for the Government of India as Assistant Adviser in Public Health Engineering for the Ministry of Works and Housing. During 1962–63, he completed an M.Sc. in Public Health Engineering. He attended the University of Ottawa, Canada, during 1970–75 and obtained a doctorate in Civil Engineering in 1975. Dr. Viraraghavan worked as a senior environmental engineer with ADI Limited, Consulting Engineers, Fredericton, N.B. during 1975–82. He joined the Faculty of Engineering, University of Regina, Regina, Saskatchewan in 1982; presently he is Professor of Environmental Engineering. He is a member on the editorial board of many journals, and is a member of many professional societies. He has a number of publications to his credit in national and international journals.

S. Vigneswaran is currently a Professor and Head of Environmental Engineering Group in Faculty of Engineering, University of Technology, Sydney, Australia. He has been working on water and wastewater research since 1976. He has published over 175 technical papers and authored two books (both through CRC press, USA). He has established research links with the leading laboratories in France, Korea, Thailand and the USA. Also, he has been involved in number of consulting activities in this field in Australia, Indonesia, France, Korea and Thailand through various national and international agencies. Presently, Dr. Vigneswaran is coordinating the university key research strengths on “water and waste management in small communities”, one of the six key research centers funded by the university on competitive basis. His research in solid liquid separation processes in water and wastewater treatment namely filtration, adsorption is recognized internationally and widely referred.

Mr. Krishnamurthy attended the Birla Institute of Technology and Science, Pilani, Rajasthan, India, during 1987–91 and graduated with a civil engineering degree in 1991. From 1991–97, he worked as a Contracts Engineer in construction companies in New Delhi, India; Muscat, Sultanate of Oman; and Abu

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