

Water Sanitation and Treatment

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This chapter will discuss water sanitation in two parts: The history of water sanitation and present water sanitation in developing and developed countries.

Before this, it is important to briefly mention the benefits of water sanitation. The benefits of water sanitation are numerous^{i,ii}. First, there is an inverse correlation between water sanitation and infectious and diarrheal diseases. As water sanitation increases in an area, the prevalence of infectious and diarrheal diseases decreases. There are many infectious diseases that are not diarrheal that are associated with poor water sanitation and treatment, such as typhoid, schistosomiasis, trachoma, and intestinal wormsⁱⁱⁱ. Second, there is an inverse correlation between fluoridation and removal of hard chemicals in the water supply and a decrease in oral ailments, such as sores and cavities (dental caries)^{iv}. Third, water treatment and sanitation^v reduces the amount of hard mineral and metal deposits that could result in poisoning, such as lead and arsenic.

1. The History of Water Sanitation:

I. The Indus Civilization to the Roman Civilization

One of the first civilizations to make a large contribution to water sanitation and hygiene is the Indus Civilization (As early as 4600 BCE) in what would be modern-day Pakistan^v. Not only did they have sewer systems in the streets, both the peasants and the wealthy had bathrooms that were on the street side of their homes next to their latrines (which were holes in the ground connected to a large cesspool). To some historians this means that they might have been stressing the importance of hygiene and cleanliness. The sewer system was covered to protect people from the dirty water and the latrines were

flushed with clean water. It is interesting as well to note that the Indus Valley cities were extremely organized and all followed the same basic plans.

Another early civilization worth mentioning were the Minoans on the modern-day island of Crete 2700 to 1400 BCE^{vi}. The drainage systems for storm water and human waste that were used are still in use today in some parts in Crete.

Lastly, the Romans (800 BCE to 300 CE) used aqueducts, storm drains, and latrines^{vii}. At first, they just used an underground sewer system for storm water run-off, and threw their human waste into the streets. They then would wash the streets almost daily, in which all of the waste would run into the storm drains. They would wash the streets with water carried by the aqueduct system, which were large above-ground pipes that carried water from the Tiber river into the city. It wasn't until later that Rome started connecting all homes to the aqueducts directly, and when latrines began being built. Some of the early pipes used were made out of lead but the largest pipe in the city of Rome is still being used today, and it is made out of stone.

II. Europe in the Middle Ages^{viii}

Sanitation and hygiene was low on the priority list in the period between 1200 and 1800 AD in Europe. Sewage was thrown into the streets in the cities, causing epidemics. In Paris, sewage was thrown into the rivers and streams, which resulted in the city smelling so foul in the summer that people often left the city in those months to live in the country. Sewer systems weren't considered important until later, when most European cities began constructing them as a result of overcrowding and therefore unbearable amounts of human waste were accumulating. These sewer systems weren't really constructed for sanitation purposes but for aesthetic purposes.

III. Industrialized Europe

Up until this point the main theory on the cause of disease was the miasmata theory. The miasmata theory stated that disease was caused by “bad air” or poisonous air^{ix}. These clouds often gathered around places that smelled foul, like the Thames River in London (where cholera outbreaks were common). The miasmata theory was used during cholera outbreaks to explain why they occurred where they did. The Thames River was used as a sewer line by many sewage plants in London, and the sewage often accumulated in certain spots on the river, where people lived nearby and their water pumps were located. This resulted in people drinking and bathing in contaminated water, which resulted in cholera outbreaks. Dr. John Snow, who believed that it wasn't the air that was causing the outbreaks, investigated these outbreaks but instead it was the water source^x. He ended up proving that it was the water source, but this wasn't really taken into consideration until after the germ theory became popular.

Louis Pasteur popularized the germ theory of disease in the late 1800s. The germ theory of disease is the theory that we have now, which basically states that microorganisms cause infectious disease^{xi}. It was without this knowledge, however, that measures taken to clean up water in cities and for medical use occurred. These theories shaped responses to water-borne and infectious disease. Industrialized Europe and the United States put in sewer systems comparable to modern-day systems and toilets. Although sewer systems were helpful in separating clean water from dirty water, modern systems of water purification didn't begin until the 20th century in the United States.

IV. The Beginnings of Modern Water Sanitation Efforts

From the end of the 19th century to the beginning of the 20th century, the connection between human waste and drinking water being made by people motivated them to create better systems to separate the two and also to treat the sewage before putting it back into their water source. Scientists were starting to prove that there was a positive correlation between turbidity in the water and the increase of microbial contamination^{xii}. Because of this, they began water filtration using sand in the early 20th century. Chlorination began in the United States, which actually developed out of discovery and use of it in the U.S. Military^{xiii}. Other methods that began to be developed in the early to mid 20th century included:

- Aeration
- Ozonation
- Flocculation
- Granular Activated Carbon Absorption
- Reverse Osmosis

2. Present-Day Water Sanitation in Developed and Developing Countries:

I. Modern Methods of Water Treatment and Purification

Before proceeding further, one should briefly define modern methods of water treatment and purification that are used in modern-day cities and also some methods used in developing countries. These include not only physical methods of water purification and sanitation but also social measures that governments and groups use to encourage water sanitation and water hygiene practices. First, the methods used in developed countries:

- Chlorination is the use of liquefied chlorine in drinking water to purify it^{xiv}. It is effective, as it kills most bacteria, but there are chlorine-resistant bacteria, and this has motivated scientists to create other methods of water purification^{xv}. Today it

is the most commonly used method of water purification in the United States and Europe, but there have been suggestions that it may have harmful side effects.

- Ozonation is the use of ozone, which is created by an electric current, in water to disinfect it and remove metals^{xvi}. It disinfects better than chlorine, but it doesn't prevent or inhibit regrowth in bacteria. It is more commonly used in Asia and Europe than the U.S., and places that do use it in the United States are still required to use chlorination by law.
- Aeration is the creation of air bubbles in water to help decrease sediments, metals, wastes, and algae growths. This is used as a secondary treatment. It doesn't actually disinfect on its own, so it has to be used in concordance with some other method of water treatment.
- Flocculation is a process where particles in the water are clumped together to make it easier for filtration^{xvii}. Certain metals are used to do this that are considered safe for consumption, such as aluminum and magnesium.
- Granular Activated Carbon Absorption is the process of using activated carbon particles to remove pollutants from the water supply^{xviii}. The carbon is usually charcoal dust. The particles are very fine and cover a large surface area, so technically, a little goes a long way. This method is also relatively safe, as carbon is safe for consumption, so it has been being used increasingly throughout the years as a source for water filtration, but it does not remove microbes, sodium, nitrates, fluoride or hardness. However, it does remove chlorine, so it is effective in being used as a home filtration device to further filter drinking water.

- Reverse Osmosis is a process where water is forced against the gradient using pressure, forcing the separation of it from particles contained inside of it. It is used in desalination and has also been shown to be effective in killing bacteria as well. It's effective but costly financially as well as environmentally; quite a bit of energy and water is used to desalinate. It's used in parts of the world that don't have naturally occurring freshwater deposits, and it can be used for personal home water filtration.
- Fluoridation of water is the process of dissolving fluoride in the water supply to prevent tooth decay. There have been some controversies surrounding the use of fluoride, as some studies have shown a relationship between bone softening and fluoridation. As a result of this, some countries have banned fluoridation.
- Boiling of water kills microbes and reduces hardness. However, it doesn't prevent regrowth of bacteria, so after a while water needs to be boiled again. A process that uses boiling is distillation, which creates water vapor, which is almost 100 percent pure water. A drawback of this method is that it also doesn't prevent regrowth, and studies have shown that the apparatus used can harbor bacteria and disease.
- Social methods can include but aren't limited to: Signs and programs about hand-washing, education about the spread and infection of waterborne diseases, and education about how to use water sanitation and purification methods.

II. Methods Used in Developing Countries and the Shift From Community-Based

Methods to Household-Based Methods

Most methods used in developed countries are too expensive and not technically feasible in countries with the largest need for clean water. Some of these methods used employ filtration using a medium such as sand or gravel^{xix}. This is often the most employed and accepted filtration in developing countries. Sand is cheap and inert, and the device can be easily made. Another method that has been used in Brazil is using an upflow solids filter, which uses a combination of a medium (such as sand) and a flocculant to decrease turbidity^{xx}. It is relatively easy and cheap to do, but not something that is widely employed yet. Both of these methods work best in really dirty water with high turbidity.

These methods are also used in combination with education about infectious disease, water sanitation, and hygiene. There have been a number of programs implemented worldwide, some of these by the World Health Organization, the CDC, the Worldbank, and UNICEF. Some of the programs are also by private companies and organizations, such as PUR's Water Project. Some projects are:

- World Water Day is a result of a UN conference in 1992 that focuses on water and improving water worldwide^{xxi}. Every year, there is a focus of world water day, for example, for 2008, the focus is on sanitation. This day brings many organizations such as WHO, UNICEF, and the Worldbank together (all children of the UN) to discuss the problems of sanitation and water in developing countries. www.worldwaterday.org
- The Water and Sanitation Program is a partnership of the World Bank^{xxii}. Its goal is to achieve the millennium development goals that were set by the UN for 2015 to decrease by 50 % the number of people without clean water or sanitation

worldwide. It supports other programs through offering monetary and educational support. The Water and Sanitation Program often discusses poverty as being a cause and an effect of poor water sanitation.

- The SafeWater System is a CDC program that provides safe and clean water to developing countries^{xxiii}. This intervention has 3 steps: 1. “point-of-use treatment” to target contaminated water using a salt solution, 2. Safe water storage in plastic containers to prevent sanitation, and 3. Behavioral changes in the community such as education about hygiene and the spread of infectious diseases.
- PUR’s water project is a project by Proctor and Gamble to provide clean water to developing countries by using sustainable methods, such as the filtration method using sand^{xxiv}. Funding this is provided partly by consumers, such as the promotion of using Proctor and Gamble coupons during the months of March and April 2008 in order to donate a liter of 1 per coupon. www.givepurwater.com.

There has also been a shift in how programs and policies approach water sanitation in developing countries. This shift has been from a community-based approach to a household-based approach.

A community-based approach is involving community leaders in the funding, implementation, and maintenance of a water sanitation and hygiene system^{xxv}. It requires that members of the community are involved in every step of the water sanitation program. These methods can also include large-scale methods, such as water piping. This method has varied based on type of community, and now there is a shift to household-based approaches to water sanitation.

Household-based approaches are small-scale, and can include the point-of-use water treatment, disinfection, and behavioral changes^{xxvi}. These are usually inexpensive.

III. Current Problems in Developed and Developing Countries

Problems in Developed Countries

Many of the problems in developed countries such as Europe and the United States involve maintaining access and availability of clean and fresh water at a low cost. A problem often mentioned is that some parts of the United States are experiencing a water shortage and drought conditions, not to mention that floods are increasing, causing exposure to waterborne and diarrheal diseases. An example of this is Hurricane Katrina's effect on the Southeast states in 2005. As a result of flooding, some people were infected with diarrheal diseases (mainly cholera), and 5 died from them.

Aside from maintaining access and availability, there is also the problem of lead contamination in some areas in developed countries. Lead enters the water from old service pipes that carry the water from treatment plants into homes^{xxvii}. The Environmental Protection Agency, or EPA, has provided a list of ways that people can reduce lead in their drinking water in their homes. These are flushing your pipes after 6 hours of non-use with cold water, only using cold water in drinking and cooking as warm water contains more lead, and getting your home tested. The EPA fact sheet also gives information about possible sources of lead contamination, what lead poisoning does to the body, and a question and answer section. The website is:

www.epa.gov/OGWDW/lead/index.html.

Another problem in developed countries is the presence of pharmaceutical drugs in the water supply^{xxviii}. There haven't been completed studies yet to discuss the possible

risks that this poses, but the causes of this are disposal of pharmaceuticals in the toilet or sink and also throwing them in the trash.

Problems in Developing Countries

The problems of water supply and sanitation in developing countries range depending on the country, but these problems can be divided into two groups: Acute and chronic or long-term. Acute problems include lack of access to a water source, lack of access to sanitized water source, and lack of sanitary bathing and toilet conditions. Many countries, especially African countries, are facing drought conditions^{xxix}. Many of their easily accessible water sources are drying up. Those with access to water often face the problem of the water being unclean and contaminated with bacteria. This can come from the use of drinking from the same water source that has been used as a latrine or as bathing water.

Chronic conditions vary, and these tend to be economic and problems with infrastructure in countries. Opinions vary depending on who it is that is discussing it. Many cite corruption, or lack of knowledge in the ability to allocate resources and money in terms of funding for water sanitation. These are just a few examples.

Conclusion

This chapter has discussed the past and present of water sanitation. The past was an overview of the trends of water sanitation up until currently, and the present discussed water sanitation in developed and developing countries.

Related Textbooks

Paul Hunter. 1997. *Waterborne Disease*.

Discusses results of poor water sanitation and discusses in depth different waterborne diseases. Also discusses chemical poisoning in the water supply and adverse affects of poor water on pregnancy.

American Water Works Association. 2003. *Water Quality*.

Focuses on water quality regulations and the different types of contaminants that can occur in the water supply.

Sources

ⁱ Sandy Cairncross and Vivian Valdmanis. 2006. "Water, Sanitation, and Hygiene Promotion." *Disease Control Priorities in Developing Countries*, 2nd ed., D.T. Jamison, J.G. Breman, A.R. Measham, G. Alleyne, M. Claeson, D.B. Evans, P. Jha, A. Mills, and P. Musgrove, 771-92. New York: Oxford University Press.

ⁱⁱ "Ten Facts on Sanitation" World Health Organization, <http://www.who.int/features/factfiles/sanitation/en/index.html>

ⁱⁱⁱ "The Health Aspects of Water Supply and Sanitation" World Health Organization, http://www.wssinfo.org/en/141_wshIntro.html

^{iv} "Oral Hygiene and Safe Water Supplies", WHO, http://www.who.int/water_sanitation_health/oralhealth/en/index5.html

^v "Indus Valley, Inc.," Discover, December 1998, pp. 67-71.

^{vi} "Minoan civilization." Encyclopædia Britannica. 2008. Encyclopædia Britannica Online. 31 Mar. 2008.

^{vii} "ancient Rome." Encyclopædia Britannica. 2008. Encyclopædia Britannica Online. 31 Mar. 2008

^{viii} Joseph and Frances Gies, 1981. *Life in a Medieval City*. New York: Harper Perennial.

^{ix} Leon Gordis, 2004. "Introduction." *Epidemiology*, 3rd Edition. Philadelphia: Elsevier Saunders.

^x John Snow. "On the Mode of the Communication of Cholera." *The Challenge of Epidemiology: Issues and Selected Readings*. Carol Buck, 1984.

^{xi} Leon Gordis, 2004. "Introduction." *Epidemiology*, 3rd Edition. Philadelphia: Elsevier Saunders.

^{xii} "25 Years of the Safe Drinking Water Act: History and Trends." 2000. Environmental Protection Agency.

^{xiii} LCDR Matthew L. Lim, CDR Gerald S. Murphy, CDR Margaret Calloway, David Tribble "History of U.S. Military Contributions to the Study of Diarrheal Diseases." *Military Medicine*, 170, 4:30, 2005

^{xiv} G.C. White. *The Handbook of Chlorination and Alternative Disinfectants*. 3rd Ed. New York: Van Nostrand Reinhold. 1992. 1308p.

^{xv} C H King, E B Shotts, Jr, R E Wooley, and K G Porter. "Survival of coliforms and bacterial pathogens within protozoa during chlorination." *Appl Environ Microbiol*. 1988 December; 54(12): 3023–3033.

^{xvi} C. Gottschalk, J.A. Libra, A. Saupe. *Ozonation of Water and Waste Water: A Practical Guide to Understanding Ozone and its Application*. Wiley-VCH, 2000.

^{xvii} John Gregory (2006) *Particles in water: properties and processes*, Taylor & Francis

^{xviii} Taraba, J. L., L. M. Heaton, and T. W. Ilvento. 1990. Using activated carbon filters to treat home drinking water, IP-6. University of Kentucky Cooperative Extension Service, Lexington, KY.

^{xix} Man, H.T., and D. Williamson. 1986. *Water Treatment and Sanitation: Simple Methods for Rural Areas*. London, Intermedia Technology Publications.

^{xx} Reid, G., and K. Coffey. 1978. *Appropriate Methods of Treating Water and Wastewater in Developing Countries*. Stilwater, Oklahoma, University of Oklahoma, Bureau of Water and Environmental Resources Research.

^{xxi} www.worldwaterday.org

^{xxii} www.wsp.org/about/index.asp

^{xxiii} www.cdc.gov/safewater

^{xxiv} www.givepurwater.com

^{xxv} Jonathan Isham and Sonia Kahkonen. "Institutional Determinants of the Impacts of Community-Based Water Services: Evidence from Sri Lanka and India". *Economic Development and Cultural Change*. Vol. 50, No. 3, (Apr 2002).

^{xxvi} Eric Mintz, et al. "Not Just a Drop in the Bucket: Expanding Access to Point-of-Use Water Treatment Systems". *American Journal of Public Health*. Vol. 91, No. 10 (Oct. 2001)

^{xxvii} "Lead in Your Water" Factsheet. Environmental Protection Agency.

<http://www.epa.gov/OGWDW/lead/lead1.html>

^{xxviii} www.nsf.org

^{xxix} Gumasai Mutumbe. "Rough Road to Sustainable Development". *Africa Renewal*. Vol. 18 No. 2 (July 2004).