TRANSMISSION AND PREVENTION OF WATER-RELATED DISEASES

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Contents

Summary

Worldwide, 1.1 billion people lack access to improved water supplies, and 2.4 billion do not have access to sanitation services. Hundreds of millions more rely on improved water supplies that are not safe because of microbial or chemical contamination. Diarrheal diseases, which are frequently transmitted by contaminated water, continue to be a leading cause of morbidity and mortality, especially among children.

There are four primary routes of transmission of water-related diseases, and each route has a set of proven disease prevention measures. The first route is water-borne transmission, in which water contaminated with pathogens is ingested and causes disease. Transmission of water-borne diseases can be prevented by assuring access to a sufficient quantity of disinfected water, proper disposal of human waste, and improved hygiene. A second route is water-washed transmission in which poor personal or

domestic hygiene results in exposure to pathogens through a person-to-person or fecal-oral mechanism. Water-washed diseases can be prevented by increasing the quantity of water available to populations and effectively promoting improved hygiene. A third route is water-based transmission through skin contact with water infested with pathogens that spend part of their life cycle in an animal that lives in water. Water-based disease transmission can be prevented by eliminating contact with infested water, controlling the populations of the intermediate hosts in water, and reducing fecal contamination of surface waters by human waste. The fourth route is water-related transmission through insect vectors that breed in water or bite near water. Prevention strategies include elimination of insect breeding sites, use of insecticide treated bednets, and reduction of insect populations.

Future directions in efforts to prevent water-related diseases include continued development of innovative, alternative, inexpensive technologies; improved implementation strategies, including community participation, formation of multi-sector partnerships, and innovative financing schemes; behavior change interventions; and integrated approaches that incorporate a variety of interventions.

1. Introduction

In 2008, just 18 years after the end of the Water and Sanitation Decade, the lack of access to improved water supplies remains a problem for over one billion people worldwide, and inadequate sanitation services affect at least 2.4 billion people. Diarrheal diseases, which are frequently transmitted by contaminated water, continue to be a leading cause of morbidity and mortality among children under 5 years old in developing countries. An estimated 1.8 million people die from diarrheal diseases each year. Greater than 80% of cases are among children under five years old. Children in this age group suffer from an average of 2.6 episodes of diarrhea each year, with the peak incidence occurring between 6 and 11 months of age. Total morbidity is estimated at 4 billion episodes per year, of which 30% are, according to one estimate, related to contaminated water. This estimate translates to roughly 1.2 billion episodes of water-related diarrheal diseases annually.

There are a number of reasons for the persistence of these problems, in spite of the investment of hundreds of billions of dollars in water and sanitation services by donor agencies and governments. Population shifts from rural to urban areas have stressed existing water and sanitary infrastructure and exceeded the capacity of many countries to keep up with demand for services. In many rural areas, water and sanitary infrastructure is inadequate or non-existent because of dispersed populations and poor transportation infrastructure. Large population dislocations caused by armed conflict and natural disasters have created enormous logistical problems in providing water and sanitation services. Finally, inadequate maintenance and repair of water and sanitation infrastructure has, in many instances, led to failures of technology to deliver safe water. Given this scenario of a large burden of disease caused by inadequate water and sanitation services, the remainder of this article takes a closer look at water-related diseases. Water can play a role in the transmission of disease in various ways. There are four primary routes of transmission of water-related diseases: water-borne, water-washed, water-based, and water-related insect vector. Each route will be discussed

followed by strategies for preventing disease transmission through that route. Future trends in water and sanitation will be considered in the final section.

2. Water-borne Diseases

Water-borne pathogens, which are largely transmitted through a fecal-oral route, are important causative agents of disease outbreaks in the developing as well as developed world. In addition, water-borne pathogens contribute to background rates of disease not detected as outbreaks and therefore not reported to public health authorities. Table 1 contains examples of water-borne diseases. The focus of the table is microbiologic agents of disease. Inorganic compounds such as arsenic and lead are also important causes of water-borne disease but will not be considered here.

Disease	Pathogen(s)	Transmission	Symptoms
Bacterial			
Cholera	*Vibrio cholerae*	Fecal-oral	Acute, profuse watery diarrhea, dehydration
Gastroenteritis	*Escherichia coli*, *Campylobacter* spp., *Salmonella* spp.	Fecal-oral, person→ person, or animal→ person	Watery or loose stools, stomach cramps
Typhoid	*Salmonella typhi*	Fecal-oral	Fever, headache, nausea, loss of appetite, constipation or diarrhea
Parasitic			
Amoebic dysentery	*Entamoeba histolytica*	Fecal-oral, person→ person	Stomach pain, bloody diarrhea, fever
Cryptosporidiosis	*Cryptosporidium parvum*	Fecal-oral, person→ person, or animal→ person	Watery diarrhea, stomach cramps
Dracunculiasis (Guinea worm)	*Dracunculus medinensis*	Person→ copepod→ person	Emergence of worm through skin causes an ulcer, severe local pain, and swelling
Giardiasis	*Giardia lamblia*	Fecal-oral, person→ person	Watery diarrhea, stomach cramps, upset stomach
Viral			
Hepatitis	Hepatitis A	Fecal-oral, person→ person	Jaundice, fatigue, abdominal pain, loss of appetite, nausea, diarrhea, fever
Viral Gastroenteritis	Norwalk virus	Fecal-oral, person→ person	Watery diarrhea, vomiting

Table 1. Several Examples of Water-borne Diseases

2.1. Transmission

Water-borne transmission refers to the acquisition of disease by exposure to pathogens through the ingestion of water contaminated with feces or inorganic substances. Water can become contaminated at the source, during transport to the home, in storage containers, or through improper handling.

Unprotected surface water (such as rivers, lakes, or springs) or ground water (such as shallow wells) can become contaminated by human or animal feces or agricultural effluent. Piped water sources can also become contaminated from a variety of factors. If source water is contaminated and is not chlorinated or otherwise treated, or if the amount of disinfectant applied is inadequate, the water delivered to the tap will likely be contaminated. Insufficiently maintained pipes may contain sediment that consumes chlorine residuals, rendering disinfection practices ineffective. Cracked pipes or crossed connections with sewer pipes can permit entry of contaminants into a water system, creating an efficient vehicle for transmission of pathogens. When power outages occur in water systems, or when power to systems is periodically interrupted in order to reduce costs or conserve water, the resultant negative pressure in the system can pull contaminants into the water system from outside. Clandestine connections (holes made in existing water pipes by persons without access to a tap) create apertures in water pipes that also allow contaminants to enter into the water system.

Source water can become contaminated during transport in fecally-contaminated containers, or if fecally-contaminated hands touch the water, for example when the mouth of a bucket is grasped to stabilize it for transport on a person's head.

Stored water can become contaminated if the storage container is fecally-contaminated, if the implement introduced into a storage vessel to remove water, such as a cup, is contaminated, if no cover is kept on the container to keep contaminants out, or if fecally-contaminated hands touch the water.

Water can be contaminated by improper handling, which can include touching water with unwashed hands, or using dirty implements to obtain water for food preparation or drinking.

2.2. Prevention

Figure 1 illustrates the ways in which water can become contaminated and how interventions can break the chain of contamination when implemented at specific points in the pathway of waterborne disease transmission.

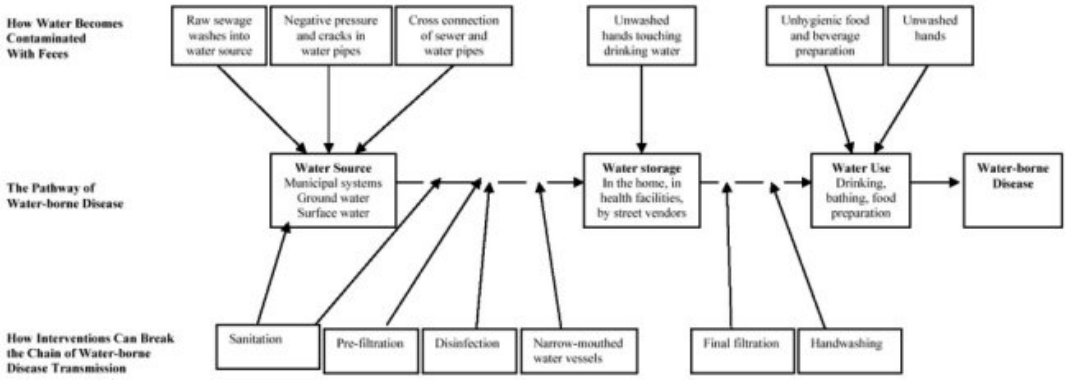

Figure 1. How Water Becomes Contaminated and How Interventions Can Break the Chain of Contamination and Prevent Waterborne Disease

These and other interventions are discussed in detail below.

2.2.1. Piped Water and Sewage Systems

Universal access to piped systems for delivery of disinfected water, and for removal, treatment, and disposal of sewage would substantially decrease water-borne disease transmission. In the 20th Century, the incidence of water-related diseases decreased dramatically in the industrialized world in response to the "sanitary revolution" that resulted in the near universal introduction of piped water and sewage systems. For example, in 1900, the average death rate from typhoid fever in the United States was 36 per 100,000 people. More than 25,000 people died of typhoid fever that year. By 1910, the death rate had dropped to 20 per 100,000 and by 1935, to 3 per 100,000. By 1960, fewer than 20 people died from typhoid fever in the entire United States.

Providing universal access to piped, treated water and sewage treatment facilities would cost hundreds of billions of dollars and take decades to achieve. Nevertheless, provision of such services is a necessary goal and should be pursued vigorously. Member countries of the United Nations recognized this need when they established the Millennium Development Goal for Water, which aims to reduce the proportion of the world's population without access to safe water by half by the year 2015. In the meantime, alternative interventions that are less expensive and more easily implemented can help reduce the burden of disease in the interim for populations lacking these services.

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Bibliography and Suggestions for further study

Black R.E. and Lanata C.F. (1995). Epidemiology of Diarrheal Diseases in Developing Countries. In: *Infections of the Gastrointestinal Tract* (Blaser M.J. et al, ed). New York: Raven Press, Ltd., 13-36. [This book chapter discusses the epidemiology of diarrheal diseases, microbial etiologies, risk factors and transmission routes, host risk factors, and strategies for prevention.]

Conant, J and Fadem P (2008). A Community Guide to Environmental Health. Hesperian Foundation. http://www.hesperian.org/mm5/merchant.mvc?Screen=PROD&Store_Code=HB&Product_Code=B160&Category_Code=ENG. [This is a practical guide to environmental health interventions that was produced by the group that wrote "Where There is No Doctor." It can be purchased or downloaded free of charge].

Centers for Disease Control and Prevention (2000). *Safe Water Systems for the Developing World: A Handbook for Implementing Household-Based Water Treatment and Safe Storage Projects*, 187 pp. Atlanta, GA. [This is a step-by-step manual designed for program managers involved in implementing a water quality improvement project. The full text and additional information are available at www.cdc.gov/safewater].

Clasen T, Roberts I, Rabie T, et al. Interventions to improve water quality for preventing diarrhoea (review). The Cochrane Library 2006 (3); (http://thecochranelibrary.com). [This is a Cochrane review of the articles documenting the health impact of point-of-use water treatment technologies].

Environmental Health at USAID Website (http://www.ehproject.org). This website contains peer-reviewed articles, fact sheets, and other references related to water, hygiene, and sanitation.

Fewtrell L., et al. (2005) Water, sanitation, and hygiene interventions to reduce diarrhea in less developed countries: a systematic review and meta-analysis. *Lancet Infectious Diseases* 5: 42-52 [This is a Cochrane review of studies conducted before June 26, 2003 that assessed the impact of water, hygiene, and sanitation interventions on disease prevention].

Ford T.E. (1999). Microbiological Safety of Drinking Water: United States and Global Perspectives. *Environmental Health Perspectives* 107, 191-206. [This is a review of data on global waterborne disease incidence].

Hutton G, and Haller L. (2004). Evaluation of the costs and benefits of water and sanitation improvements at the global level. Geneva. [This is a report of an analysis of costs and benefits of interventions to improve water and sanitation services. It is available on the internet at: http://www.who.int/water_sanitation_health/wsh0404/en/index.html].

Sobsey M. (2004) Managing water in the home: accelerated health gains from improved water supply. [This report describes and reviews the evidence of the health impact for a variety of household water treatment and storage technologies. It is available on the internet at http://www.who.int/water_sanitation_health/dwq/wsh0207/en/index.html]

World Health Organization and United Nations Children's Fund. (2000). *Global Water Supply and Sanitation Assessment 2000 Report*, 80 pp. Geneva. [This report presents the findings of a WHO/UNICEF assessment of global water supply and sanitation coverage. It is available on the internet at www.who.int/water_sanitation_health/Globassessment/GlobalTOC.htm].

Biographical Sketches

Jon Macy, MPH is a doctoral student in health behavior at Indiana University. He is also project director for a 25-year longitudinal study on attitudes and behaviors related to cigarette smoking. Previously, he worked as a research epidemiologist in the Foodborne and Diarrheal Diseases Branch at the Centers for Disease Control and Prevention where he collaborated with partners to implement and evaluate water quality improvement interventions in developing countries. His consulting experience includes projects with local community-based organizations, UN agencies, and NGOs, both in the United States and in developing countries.

Robert Quick, MD, MPH is a medical epidemiologist in the Foodborne and Diarrheal Diseases Branch at the Centers for Disease Control and Prevention. For the past 15 years, he has conducted research on the etiology, control, and prevention of enteric diseases in the developing world. His work on cholera in Latin

America and Africa revealed the seriousness and extent of the problem of lack of access to safe water and sanitation in the developing world and inspired a research focus on waterborne diseases and their prevention. He has collaborated with numerous partners from the public and private sectors, NGOs, UN agencies, and academic institutions to implement and evaluate water and hygiene interventions in vulnerable populations, including people living with HIV/AIDS.