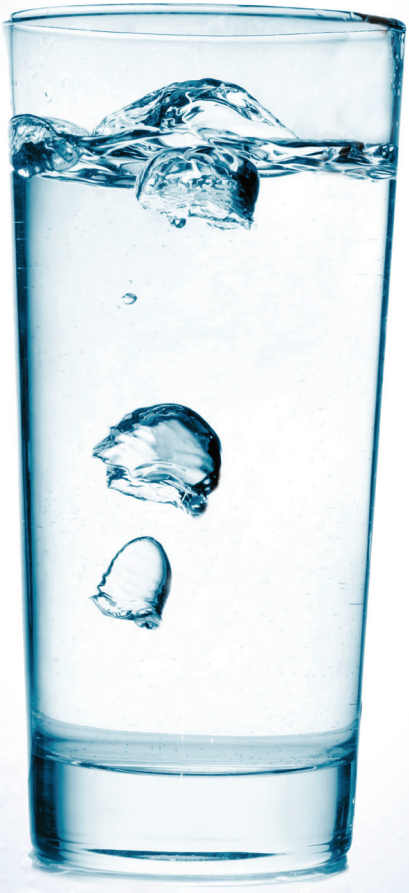
MICROBIOLOGY OF DRINKING WATER PRODUCTION AND DISTRIBUTION



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To Benjamin Noah and to all my family across the oceans.
This book is dedicated to all the children around the world who do not have access to safe drinking water.

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PREFACE

In industrial countries, we take safe drinking water for granted. Due to an increase in world population, the microbiological safety of drinking water is becoming a worldwide concern. Following a meeting of drinking water experts in 1995, it was predicted that water safety will be a major concern in the 21st century (Ford and Colwell, 1996). Concerns have been raised over the emergence of antibiotic resistance and chlorine-resistant microorganisms such as *Cryptosporidium*. Consequently, the largest documented waterborne cryptosporidiosis outbreak occurred in 1993 in Milwaukee, Wisconsin, where 403,000 people became ill, resulting in 4400 hospitalized patients and 54 deaths. Furthermore, aging populations in developed countries and increasing use of immunosuppressive drugs have led to decreased immunity to waterborne pathogens and parasites. The problems are more serious in developing countries who suffer from unsafe drinking water and poor sanitation, and where children are, unfortunately, the main victims of infectious and parasitic diseases.

The long-term effects of chemical toxicants in drinking water have received much attention by investigators and, comparatively, less efforts have been devoted to the microbiological safety of this precious resource.

This book is divided into 10 chapters. The first chapter introduces the reader to the topic of microbial pathogens and parasites of concern in drinking water safety. Chapter 2 deals with the microbiology of the treatment processes involved in conventional water treatment plants. Advances in drinking water research followed by the establishment of multiple barriers against microbial pathogens and parasites have significantly increased the safety of the water we drink daily. This multiple-barrier system includes source water protection, reliable water treatment (pretreatment, coagulation, flocculation, sedimentation, filtration, disinfection, water softening, membrane filtration, activated carbon treatment, and the potential use of nanotechnology for water purification). Household water treatment processes via the use of point-of-use (POU) devices are also included in this chapter. Chapter 3 discusses the disinfection step that is an essential and final barrier against human exposure to disease-causing pathogenic microorganisms, including viruses, bacteria, and protozoan parasites. Disinfection of drinking water is probably the most significant preventive measure in human history. Many waterborne outbreaks are attributed to the degradation of water quality in water distribution systems (WDS) through cross-connections, main breaks, back siphonage,

or negative pressure events. The main topic covered in Chapter 4 is biofilm microbiology with emphasis on biofilm formation and the factors involved in its development in water distribution pipes. The fate of pathogens (e.g., nontubercular mycobacteria, *Legionella*, protozoan parasites, enteric viruses, and opportunistic pathogens in general) is also covered. Chapter 5 covers other microbiological topics of concern in WDS. These topics include taste and odor problems, cyanotoxins produced by cyanobacteria, fungi, protozoa with emphasis on free living amoebas, microinvertebrates, iron and manganese bacteria, and the occurrence of nitrifying bacteria. Chapter 6 deals with the biotreatment and biostability of drinking water and covers the various methods used to assess biostability of drinking water. Drinking water safety can be compromised by the deliberate or accidental contamination of drinking water resources. Chapter 7 covers the major biowarfare microbial agents and biotoxins that could be used to deliberately contaminate drinking water. An estimated 1.1 billion of the world's population does not have access to safe clean water, and approximately 2.6 billion people lack improved sanitation. As a result, approximately 2.2 million people die each year from waterborne diseases. The World Health Organization estimates that endemic diarrhea accounts for 17% of all deaths among children less than 5 years of age. Chapter 8 covers the major treatment technologies for improving the quality of drinking water in developing countries. Chapter 9 addresses the topic of bottled water microbiology. Although bottled water is a useful resource in emergency situations, its quality may sometimes be contaminated via introduction of microbial pathogens at the source or during bottling. Chapter 10 describes the steps involved in quantitative microbial risk assessment (QMRA) and gives examples of the use of risk assessment to estimate the risk of exposure to bacterial, viral, and protozoan pathogens and predict the burden of waterborne diseases on a given community.

This book can serve as a textbook for courses on drinking water microbiology and would be useful in other courses in environmental engineering programs. Due to the author's extensive review of the literature pertaining to drinking water microbiology, this book can also serve as a reference text for engineers and scientists interested in the interface between public health microbiology and drinking water treatment and distribution.

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Gainesville, FL
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MICROBIAL CONTAMINANTS IN DRINKING WATER

1.1 INTRODUCTION

In water treatment plants, the goal is to produce pathogen- and parasite-free drinking water, not necessarily sterile water. There are, however, several sources of contamination in a potable water system (Percival et al., 2000):

- Drinking water source (see Chapter 2).
- Inadequate treatment in the water treatment plant.
- Water distribution system (WDS): Treated water quality may deteriorate in the distribution system. Pathogens and parasites may be introduced into treated water through cracks in the water pipes, back-siphonage or cross-contamination.
- Biofilm development which may alter water quality.

This chapter surveys the major microbial pathogens and parasites which may contaminate drinking water.

1.2 TRANSMISSION ROUTES OF PATHOGENS AND PARASITES

Transmission involves the transport of an infectious agent from the reservoir to a host. It is the most important link in the chain of infection. Pathogens can be transmitted from the reservoir to a susceptible host by various routes. The transmission pathways of water-related pathogens are summarized in Figure 1.1 (WHO, 2011c).

1.2.1 Person-to-Person Transmission

The most common route of transmission of infectious agents is from person to person. Examples of direct contact transmission are the sexually transmitted diseases such

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