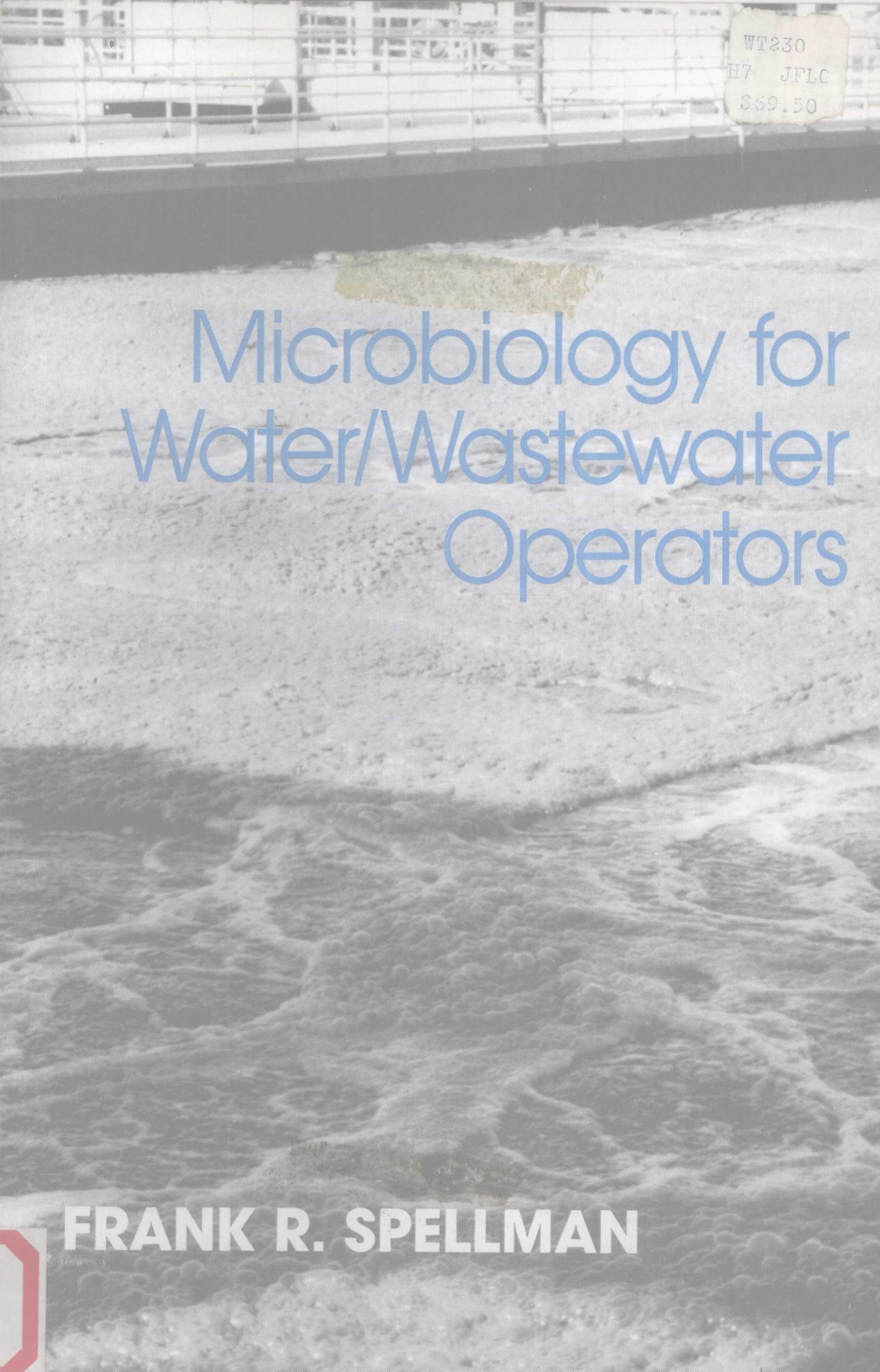

Microbiology for Water/Wastewater Operators

FRANK R. SPELLMAN

Microbiology for Water/Wastewater Operators

FRANK R. SPELLMAN, Ph.D.

ENVIRONMENTAL HEALTH & SAFETY MANAGER
HAMPTON ROADS SANITATION DISTRICT
VIRGINIA BEACH, VIRGINIA

TECHNOMIC
PUBLISHING CO., INC.
LANCASTER · BASEL

Microbiology for Water/Wastewater Operators
a**TECHNOMIC** publication

Published in the Western Hemisphere by
Technomic Publishing Company, Inc.
851 New Holland Avenue, Box 3535
Lancaster, Pennsylvania 17604 U.S.A.

Distributed in the Rest of the World by
Technomic Publishing AG
Missionsstrasse 44
CH-4055 Basel, Switzerland

Printed in the United States of America
10 9 8 7 6 5 4 3 2 1

Main entry under title:
Microbiology for Water/Wastewater Operators

A Technomic Publishing Company book
Bibliography: p. 185
Includes index p. 189

Library of Congress Catalog Card No. 96-60785
ISBN No. 1-56676-439-4

PREFACE

THIS book is designed to provide a comprehensive discussion of microbiological concepts as they relate to water and wastewater. This book assumes no prior knowledge of microbiology. From the first page on, it builds an integrated picture of the structure, growth, morphology, and metabolism of microorganisms; these fundamental concepts are central to all areas of microbiology—including bacteriology, water/wastewater treatment, and environmental science. Sufficient background information and reference to microbiological and bacteriological principles and practices are presented throughout the text to provide readers with an understanding of the various concepts and organisms under discussion. Subsequent chapters and the Appendix deal with practical applications of microbiology and also cover identification of microorganisms, aseptic technique, fecal-coliform isolation, identification, and verification. Moreover, operational troubleshooting hints are included for personnel who are concerned with the operational conditions existing in activated sludge systems.

This book can be used as a basic study tool by water/wastewater personnel who are preparing for their licensing examinations or as a supplemental text in undergraduate or graduate courses in aquatic ecology, water/wastewater pollution control, and environmental science courses dealing with water biology. It can also be consulted as a biological/environmental science reference text by municipal, school, and water/wastewater resource libraries.

I would like to acknowledge the numerous contributions made to this book in the area of microbiological laboratory practices by the Water Quality Department of Hampton Roads Sanitation District (HRSD), Virginia Beach, Virginia. Without a doubt, the department has the finest group of wastewater laboratory specialists anywhere. For specific professional assistance I am also grateful to Robert Maunz, Laboratory Specialist A, and to Nancy Davis, Laboratory Technician, HRSD. Without their assistance, many of the practical applications addressed in this book would not have been correct. And, of course, without the help of my two associates, Jennifer Rodrigues and Rosalyn Hopkins, this book would not have been possible.

Finally, I am inspired to write something about environmental science whenever I look upon my granddaughter's (Rachel Morgan Spellman) shining, smiling face. I guess it is the innocence and helplessness that I really see. I look at her and wonder if she understands the place in time that we now occupy on earth in relation to our environment and if she and her friends will have a place to live where the water is clean—free of disease and pollution. Will she have the chance to grow to old age and gain the wisdom to understand that she was born of water and needs to be sustained by it?

I hope so!

FRANK R. SPELLMAN

PART 1

Fundamental Concepts

CHAPTER 1

Introduction

> Water is sometimes sharp and sometimes strong, sometimes acid and sometimes bitter, sometimes sweet and sometimes thick or thin, sometimes it is seen bringing hurt or pestilence, sometimes health-giving, sometimes poisonous. It suffers change into as many natures as are the different places through which it passes. And as the mirror changes with the color of its object, so it alters with the nature of the place, becoming: noisome, laxative, astringent, sulfurous, salt, incarnadined, mournful, raging, angry, red, yellow, green, black, blue, greasy, fat or slim. Sometimes it starts a conflagration, sometimes it extinguishes one; is warm and is cold, carries away or sets down, hollows out or builds up, tears down or establishes, fills or empties, raises itself or burrows down, spreads or is still; is the cause at times of life or death, or increase or privation, nourishes at times and at others does the contrary; at times has a tang, at times it is without savor, sometimes submerging the valleys with great flood. In time and with water, everything changes.
>
> Leonardo da Vinci

THROUGH experience, water and wastewater specialists come to know many of the characteristics of water described by da Vinci. It is, however, the possibility that water can "bring hurt and pestilence" to other organisms that most interests water and wastewater specialists.

Water treatment specialists are concerned with water supply and water purification through a treatment process. In treating water, the primary concern is producing potable water that is safe to drink (free of pathogens) with no accompanying offensive

characteristics such as foul taste and odor. The water specialist must possess a wide range of knowledge in order to correctly examine water for pathogenic microorganisms and to determine the type of treatment necessary to ensure that the water quality of the end product, potable water, meets regulatory standards.

Wastewater treatment specialists are also concerned with water quality. However, they are not as concerned as water specialists are with total removal or reduction of most microorganisms. The wastewater treatment process actually benefits from microorganisms that act to degrade organic compounds and, thus, stabilize the organic matter in the waste stream. Thus, wastewater specialists must be trained to operate the treatment process in a manner that controls the growth of microorganisms and puts them to work in the stabilization process. Moreover, to more fully understand wastewater treatment, it is necessary to determine which microorganisms are present and how they function to break down the components in the wastewater stream. Then, of course, the wastewater specialist must ensure that before dumping treated effluent into a receiving body, the microorganisms that worked hard to degrade organic waste products, especially the pathogenic microorganisms, are not sent from the plant as viable organisms.

The average citizen living in the United States or Europe has heard of waterborne disease-causing microorganisms, but in this modern age he or she probably does not give them a second thought. Modern sanitation practices have made contraction of most of the waterborne diseases, shown in Table 1.1, rare in the United States and Europe. This is not the case, however, in other areas of the world. It would be foolhardy (and deadly) for us to forget that disease-causing organisms are still in our environment.

In the water environment, Koren (1991) points out that water is not a medium for the *growth* of microorganisms, but is instead a means of transmission (a conduit for; hence, the name *waterborne*) of the pathogen to the place where an individual is able to consume it and there start the outbreak of disease. This is contrary to the view taken by the average person. That is, when the topic of waterborne disease is brought to his/her attention, he/she might mistakenly assume that waterborne diseases are

Table 1.1. Waterborne disease-causing organisms.

Microorganism	Disease
Bacterial	
Escherichia coli	
Salmonella typhi	Typhoid fever
Salmonella sp.	Salmonellosis
Shigella sp.	Shigellosis
Yersinia entercolitica	Yersiniosis
Vibrio cholerae	Chlorea
Campylobacter jejuni	Campylobacter enteritis
Intestinal parasites	
Entamoeba histolytica	Amebic dysentery
Giardia lamblia	Giardiasis
Cryptosporidium	Cryptosporidiosis
Viral	
Norwalk agent	—
Rotavirus	—
Enterovirus	Polio Aseptic meningitis Herpangina
Hepatitis A	Infectious hepatitis
Adenoviruses	Respiratory disease Conjunctivitis

at home in water. Nothing could be further from the truth. A water-filled *ambience* is not the environment in which the pathogenic organism would choose to live, that is, if it had such a choice. The point is that microorganisms do not normally grow, reproduce, languish, and thrive in watery surroundings. Pathogenic microorganisms temporarily residing in water are simply biding their time, going with the flow, waiting for their opportunity to meet up with their unsuspecting host or hosts. To a degree, when the pathogenic microorganism finds its host or hosts, it is finally home or may have found its final resting place.

Water treatment operations generally focus on operating, monitoring, and determining settings for chemical feed machines and high pressure pumps and boilers. Likewise, wastewater treatment operations are also concerned with the general

aspects of process flow treatment and management. The important point is that neither of these water treatment specialties can accomplish their missions without having a well-rounded, fundamental knowledge of the science of microbiology. This is important. For example, the water specialist who is well grounded in microbiological concepts is equipped to operate his or her plant in a manner that will provide safe, sanitary, palatable quality drinking water for domestic consumption. Likewise, the wastewater specialist who has knowledge of microbiological concepts is equipped to operate wastewater treatment plant processes in a manner that will produce effluent of better quality (hopefully) than the water contained in the receiving body.

As related above, it would be impossible for the water or wastewater specialist to fully comprehend the principles of effective water/wastewater treatment without having knowledge of the fundamental factors concerning microorganisms and their relationships to one another, their effect on the treatment process, and their impact on the environment, human beings, and other organisms. Thus, the intention of this text is to provide a fundamental knowledge of microbiology for water and wastewater specialists. In order to provide this fundamental knowledge, we will pursue a structured approach that is basic but far reaching.

MICROBIOLOGY

Microbiology is the study of organisms that are of microscopic dimensions and thus cannot be seen except with the aid of a microscope. Microbiologists are scientists who are concerned with studying the form, structure, reproduction, physiology, metabolism, and identification of microorganisms. The microorganisms they study generally include bacteria, fungi, protozoa, algae, and viruses. These tiny organisms make up a large and diverse group of free-living forms that exist either as single cells, cell bunches or clusters. Any and all of these organisms may be found in water and/or wastewater.

Microscopic organisms can be found in abundance almost anywhere on earth. The vast majority of microorganisms are not

harmful. Many microorganisms, or microbes, occur as single cells (unicellular); others are multicellular; and still others, viruses, do not have a true cellular appearance.

Because microorganisms exist as single cells or cell bunches, they are unique and distinct from the cells of animals and plants, which are not able to live alone in nature but can exist only as part of multicellular organisms (Brock & Madigan, 1991). A single microbial cell, for the most part, exhibits the characteristic features common to other biological systems, such as metabolism, reproduction, and growth.

CLASSIFICATION

For centuries, scientists classified the forms of life visible to the naked eye as either animal or plant. Much of the current knowledge about living things was organized by the Swedish naturalist Carolus Linnaeus in 1735.

The importance of classifying organisms cannot be overstated, for without a classification scheme, it would be difficult to establish a criteria for identifying organisms and to arrange similar organisms into groups. Probably the most important reason for classifying organisms is to make things less confusing (Wistreich & Lechtman, 1980).

Linnaeus was quite innovative in the classification of organisms. One of his innovations is still with us today: *the binomial system of nomenclature.* Under the binomial system all organisms are generally described by a two-word scientific name, the *genus* and *species.* Genus and species are groups that are part of a hierarchy of groups of increasing size, based on their nomenclature (taxonomy). This hierarchy follows.

Kingdom
Phylum
Class
Order
Family
Genus
Species

Utilizing this hierarchy and Linnaeus's binomial system of nomenclature, the scientific name of any organism (as stated previously) includes both the genus and the species name. The genus name is always capitalized, while the species name begins with a lowercase letter. On occasion, when there is little chance for confusion, the genus name is abbreviated with a single capital letter. The names are always in Latin, so they are usually printed in italics or underlined. Some organisms also have English common names. Some microbe names of interest in water/wastewater treatment follow.

- *Salmonella typhi*—the typhoid bacillus
- *Escherichia coli*—a coliform bacteria
- *Giardia lamblia*—a protozoan

Escherichia coli is commonly known as simply *E. coli,* while *Giardia lamblia* is usually referred to by only its genus name, *Giardia.*

A simplified system of microorganism classification is used in water and wastewater. Classification is broken down into the kingdoms of animal, plant, and protista. As a general rule the animal and plant kingdoms contain all the multicell organisms, and the protists contain all single-cell organisms. Along with microorganism classification based on the animal, plant, and protista kingdoms, microorganisms can be further classified as

Table 1.2. Simplified classification of microorganisms.

Kingdom	Members	Cell Classification
Animal	Rotifers Crustaceans Worms and larvae	Eucaryotic
Plant	Ferns Mosses	
Protista	Protozoa Algae Fungi	
	Bacteria Lower algae forms	Procaryotic