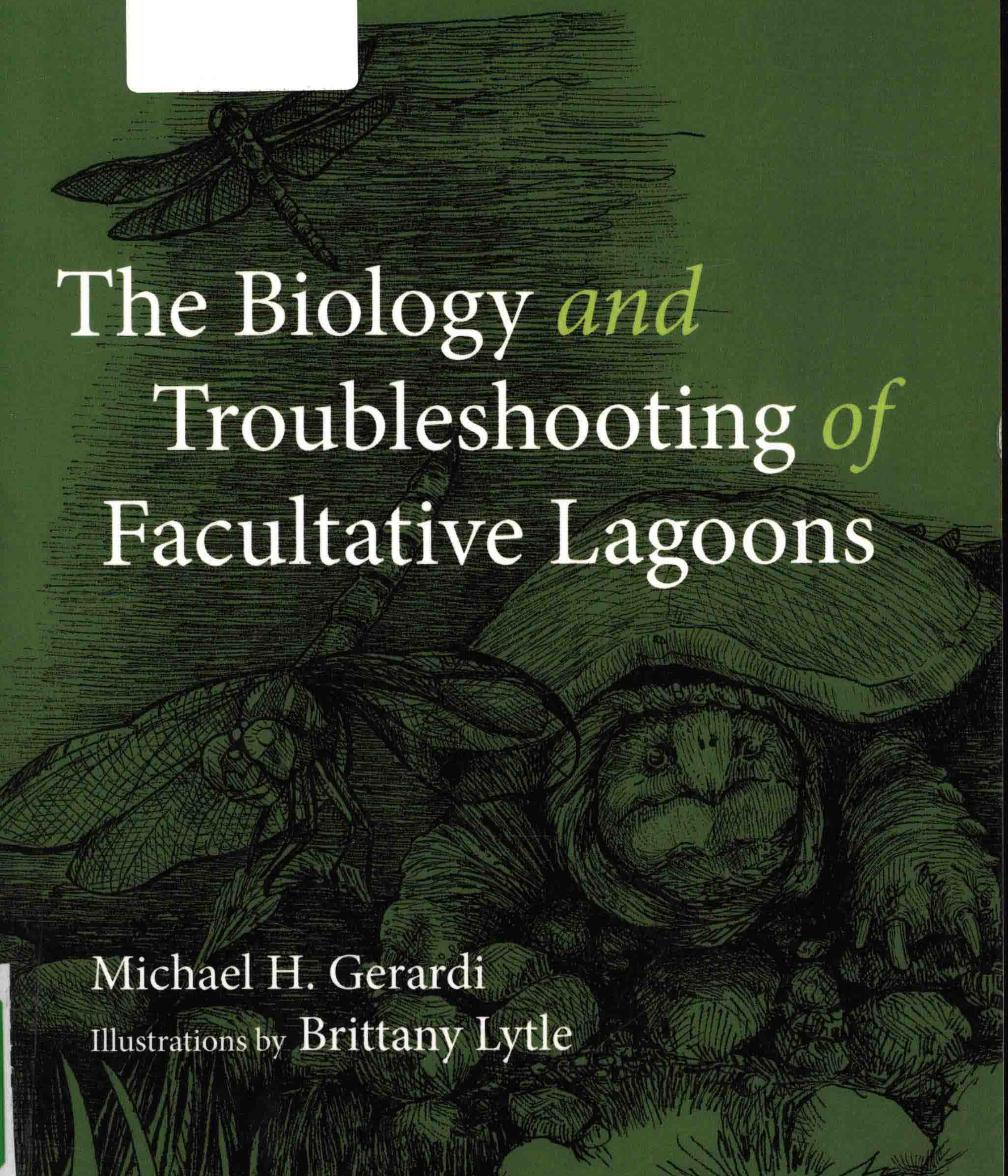
Wastewater Microbiology Series

The Biology *and* Troubleshooting *of* Facultative Lagoons



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WASTEWATER MICROBIOLOGY SERIES

Editor

Michael H. Gerardi

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The Biology and Troubleshooting of Facultative Lagoons
Michael H. Gerardi

In loving memory of
Pauline Testa Gerardi

Preface

Facultative lagoons are commonly used for the treatment of domestic, municipal, and industrial wastewaters. They often are more appropriate for use than conventional forms of secondary treatment in developing countries. However, as discharge requirements become more stringent, a review of the biological, chemical, and physical interactions in facultative lagoons is critical for the successful operation and compliance with discharge requirements.

This book provides operators, laboratory technicians, and engineers with a review of the critical roles of microscopic and macroscopic organisms that live in and around lagoons. Proper design parameters for facultative lagoons have been addressed in numerous texts and other publications, including those of federal and state regulatory agencies. For that reason, this text does not address and enumerate those parameters. This book provides biological and chemical approaches to understanding facultative lagoons and includes presentations on algae, archaea, bacteria, crustaceans, duckweed, aquatic and immature insects, grasses, rotifers, watermeal, weeds, worms, and burrowing animals. The text also presents descriptions of the natural processes of wastewater treatment with algae, bacteria, and other organisms and operational problems that can occur, their identification, prevention, and control.

Monitoring and troubleshooting lagoons for acceptable operational conditions, process control measures, and acceptable effluent quality is not always simple. The biological and chemical processes involved in wastewater treatment are numerous and often complex. This book is written for lagoon operators who may not have the opportunity or time to obtain the training that they need for reviewing these natural processes.

A review of the biological, chemical, and natural physical treatment processes that occur in aerobic, facultative, and anaerobic zones of a facultative lagoon is presented. Critical biochemical reactions described include aerobic and anaerobic respiration, fermentation, photosynthesis, and changes in pH and alkalinity. Control measures for the excessive growth of algae, duckweed, watermeal, and rooted plants as well as control measures for midges and mosquitoes and odors are offered.

Today, there is increasing pressure to replace wastewater lagoons with conventional processes. This pressure is due to the concern to whether or not facultative lagoons can keep pace with ever-changing regulations. However, facultative lagoons can be upgraded and operated to produce an effluent that is comparable to conventional treatment processes. This book presents the biological, chemical, and physical processes that affect wastewater treatment and their corresponding changes in lagoon microbial ecosystems. An understanding of these changes can provide an operator with problem-solving leverage and improved effluent quality.

The *Biology and Troubleshooting of Wastewater Lagoons* is the eighth book in the Wastewater Microbiology Series by John Wiley & Sons. The series is designed for wastewater personnel, and it presents a microbiological review of the significant groups of organisms and their roles in wastewater treatment facilities.

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Part I

Overview

1

Introduction

Lagoons are one of the oldest wastewater treatment systems. They consist of inground, earthen basins where wastewater is received, held for a period of time, treated, and then discharged (Fig. 1.1). Depending on the composition, strength, and volume of wastewater to be treated and discharge requirements, a predetermined "hold" or retention time for the wastewater is used. Although lagoons are simple in design, there are many complex biological, chemical, and physical processes that occur in lagoons. There are several different terms for lagoons. Many of these terms are used interchangeably. These terms include pond, oxidation pond, polishing pond, sewage pond, stabilization pond, maturation pond, and cell. Some terms refer to the role of the lagoon in a wastewater treatment process (Table 1.1).

Lagoons or natural impoundments were used in the United States in the 1920s to capture liquid wastes. With increasing knowledge of the wastewater treatment ability of lagoons, they were and are used to treat agricultural, domestic, industrial, and municipal wastes and wastewaters.

Lagoons became popular in the 1950s. Today, numerous lagoons and lagoon systems are used, especially in rural areas for the treatment of domestic and municipal wastewaters. Although performance varies from good to bad, lagoons that are properly designed, constructed, and operated can produce effluent that meets secondary treatment standards.

Lagoons are one of the most popular, simplest, and least expensive technologies for treating wastewater. Lagoons do require relatively large amounts of land. For each million gallons per day (MGD) of wastewater, approximately 30 acres of lagoon are required for 50 pounds biochemical oxygen demand (BOD) per acre per day. Some "once-through" lagoons are as large as 40 MGD.

The Biology and Troubleshooting of Facultative Lagoons, First Edition. Michael H. Gerardi.

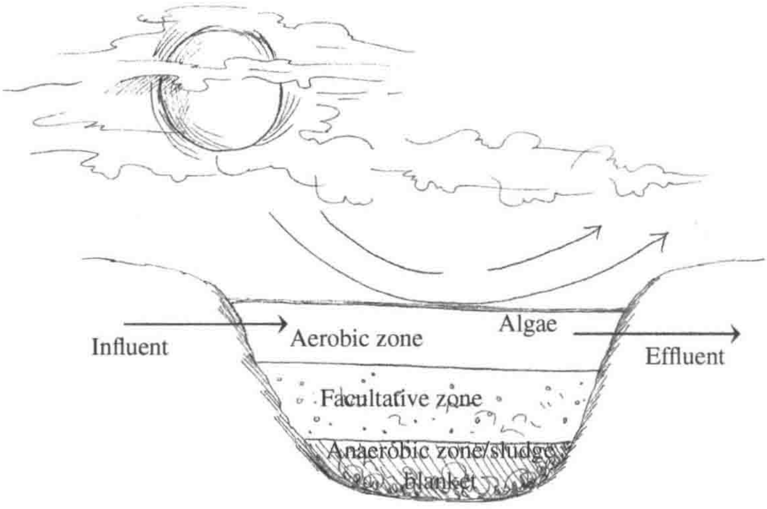

Figure 1.1 *Facultative lagoon. A facultative lagoon has three active microbial zones where wastewater is treated. The zones consist of aerobic, facultative, and anaerobic habitats.*

TABLE 1.1 **Terminology for lagoons or ponds**

Term	Description
Maturation	Improves effluent from activated sludge process or trickling filter to tertiary quality, principally to reduce the number of pathogens and nutrients
Oxidation	Wastewater is purified by sedimentation and aerobic and anaerobic treatment
Polishing	Increases the environmental quality of effluent from previous treatment
Primary	Receives raw (unsettled) wastewater and has a sludge layer that is responsible for methane production
Secondary	Receives settled wastewater or effluent from an anaerobic lagoon
Stabilization	An anaerobic, facultative, or maturation lagoon

TABLE 1.2 **Advantages of lagoons as compared with more advanced wastewater treatment processes**

Can handle intermittent use and shock loads better than other processes
Inexpensive to construct
Relatively small quantity of equipment is needed
Reduced maintenance costs
Relatively simple to operate
Effective in removing pathogens
Effluent often suitable for irrigation due to high nutrient content
Fewer solid-handling problems

Lagoons use natural and energy-efficient processes to provide low-cost wastewater treatment, and they offer an alternative to more advanced wastewater treatment processes. Although lagoons offer many advantages such as reduced maintenance cost when compared with other wastewater treatment systems (Table 1.2), they also have disadvantages such as the requirement for large amounts of land (Table 1.3).

Lagoons are designed to satisfy a specific site and need. The design is based on several factors including type of soil, amount of land area required, climate, quantity and composition of the wastewater to be treated, and discharge requirements. However, lagoon effluent may require additional treatment or polishing to remove pathogens or nutrients.

TABLE 1.3 Disadvantages of lagoons as compared with more advanced wastewater treatment processes

Less efficient in cold climates than other processes
Require large amounts of land
Effluent quality varies with seasonal changes in wastewater temperature
Effluent from facultative lagoons contains algae and may require additional treatment to meet discharge requirements
Seasonal turnover and release of benthic organisms
System upsets usually result in odor production
If not properly maintained, lagoons can provide a breeding area for midges, mosquitoes, and other insects

Most lagoons are found in small rural communities. Here, lagoons often cost less to construct, operate, and maintain than other wastewater treatment systems. Although lagoons require more land than other wastewater treatment systems, land is usually more available and affordable in rural areas. Because lagoons treat a large variety of wastes, they must be properly constructed to prevent soil and groundwater contamination.

Wastewater lagoons must be sealed or lined to prevent seepage at the bottom and sidewall of the lagoon to prevent subsurface and groundwater contamination. There are several types of liners that are used: (i) clay, cement, and asphalt; (ii) synthetic and rubber; and (iii) natural. Most liners typically perform well for 15 years. However, premature failure can occur and is usually due to (i) cleaning or dredging operations, (ii) membrane puncture, (iii) scour of cover material, (iv) substandard liner material, and (v) weed growth. The most commonly used liners for industrial wastewater lagoons include (i) chlorosulfonated polyethylene or Hypalon®, (ii) polypropylene (rPP), (iii) polyvinyl chloride, (iv) reinforced liner—low density, and (v) XR-5®/XR3®. These liners are tolerant of ice buildup and exposure to harsh and prolonged sunlight.

Clay liners shrink and swell according to wastewater temperature and wet-and-dry conditions. However, compacted clay liners are susceptible to erosion and vegetative growth in the dike. These conditions damage the integrity and strength of the liner and dike.

Installation of clay requires proper moisture content and compaction. Cement and asphalt liners can crack under temperature change and wet-and-dry conditions. Synthetic liners are commonly used and usually consist of some type of plastic. They require careful installation by an experienced contractor. If the liner is properly installed and is not punctured, seepage does not occur. Synthetic liners are inert and therefore, they are often used in lagoons that contain toxic wastes.

The clogging of soil pores forms natural liners. This occurs due to (i) settled solids, (ii) microbial growth, and (iii) chemical clogging of the soil due to ionic charges. However, natural liners tend to be unreliable because these natural modes for forming a natural liner or sealant are dependent on changing characteristics of the wastewater.

Large and diverse populations of archaea, algae (Fig. 1.2), bacteria, and protozoa (Fig. 1.3) are found in lagoons. Changes in numbers and dominant groups or species of organisms depend on biotic (biological) and abiotic (chemical and physical) factors (Tables 1.4 and 1.5). The most important abiotic factors are (i) composition and strength of the influent, (ii) dissolved oxygen, (iii) pH, (iv) temperature, and (v) sunlight.

The organisms found in facultative lagoons are more diverse than those found in many other biological, wastewater treatment processes including aerated and anaerobic lagoons. The