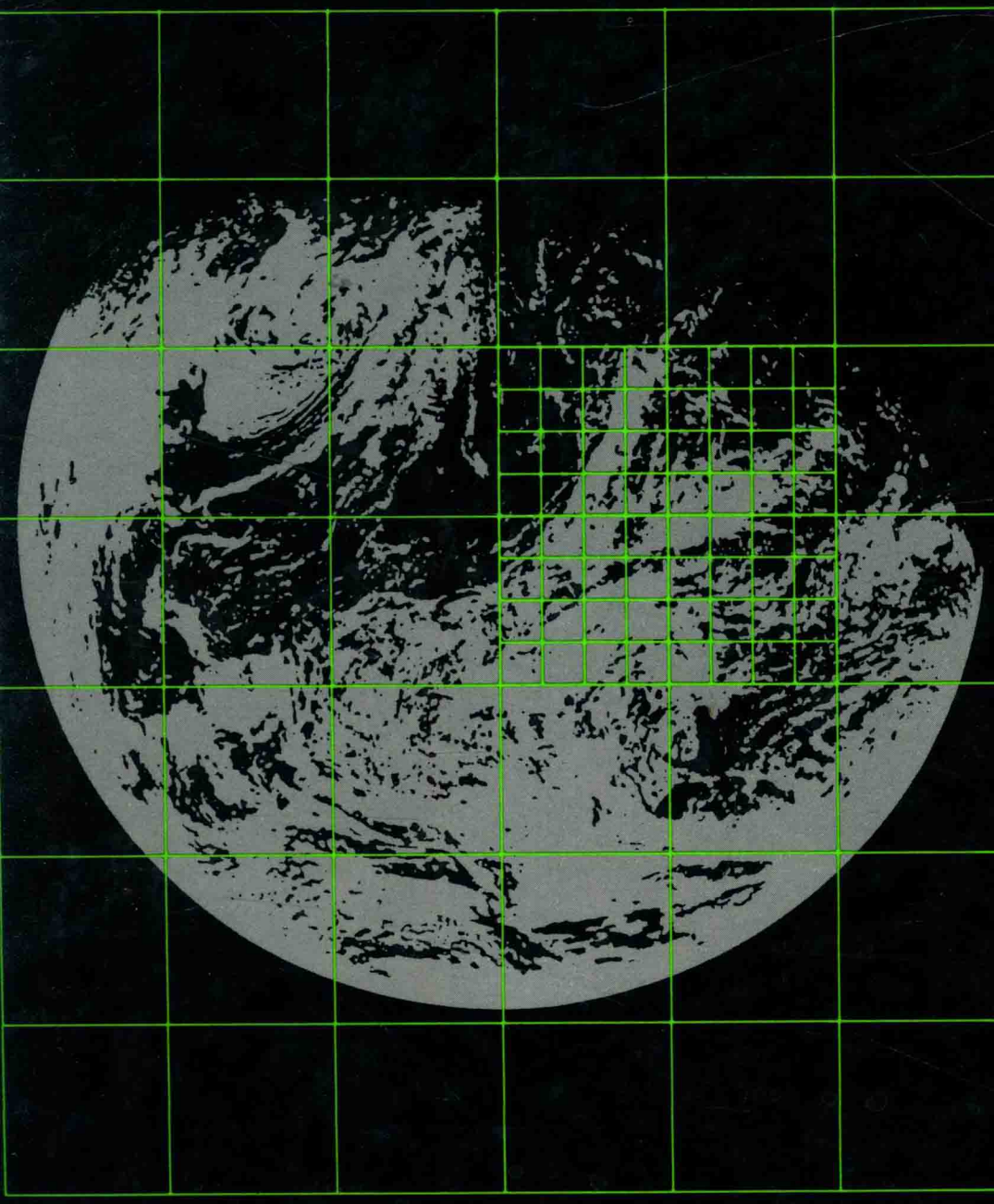
ENVIRONMENTAL ENGINEERING

Second Edition



P. Aarne Vesilind • J. Jeffrey Peirce • Ruth Weiner

Butterworths

ENVIRONMENTAL ENGINEERING

Second Edition

P. Aarne Vesilind

Department of Civil and
Environmental Engineering
Duke University
Durham, North Carolina

J. Jeffrey Peirce

Department of Civil and
Environmental Engineering
Duke University
Durham, North Carolina

Ruth F. Weiner

Huxley College of
Environmental Engineering
Western Washington University
Bellingham, Washington

Butterworths

Boston London Singapore Sydney Toronto Wellington

Library of Congress Cataloging-in-Publication Data
Vesilind, P. Aarne.
Environmental engineering.
Includes bibliographical references and index.
1. Environmental engineering. 2. Sanitary engineering. I. Peirce, J. Jeffrey. II. Weiner, Ruth F. III. Title
TD146.V47 1988 628 87-30913
ISBN 0-409-90050-8

British Library Cataloguing in Publication Data
Vesilind, P. Aarne
Environmental engineering.—2nd ed.
1. Environmental engineering
I. Title II. Peirce, J. Jeffrey II. Weiner, Ruth F.
620.8 TD145
ISBN 0-409-90050-8

Butterworth Publishers
80 Montvale Avenue
Stoneham, MA 02180

10 9 8 7 6 5 4 3 2 1

Printed in the United States of America

Preface

In environmental engineering *everything matters*. The natural sciences, the social sciences, and the humanities can be just as important to the discipline of environmental engineering as classical engineering skills such as mathematics and fluid mechanics. For many environmental engineers, this attribute of the profession provides the challenge and reward in their careers. For universities, however, the fact that everything matters creates havoc in the design of courses and course content. The problem is most critical in deciding what material to include in an introductory book on environmental engineering.

We respond to this challenge by organizing this text into the five areas most important to environmental engineers: water resources, air quality, solid and hazardous wastes (including radioactive waste), noise, and social and ethical considerations. We begin with a short introduction on the roots of environmental engineering and present the concept of risk and safety in Chapter 2. These principles surface in almost all of the subsequent chapters. The last chapter deals with environmental ethics, an important and emerging component of engineering in general. The ethics material can be used for the last few class meetings, or it can be introduced at any point in the course.

This book is intended for junior or senior level engineering students who have already been introduced to fluid mechanics and water resources engineering. Basic concepts of hydraulics are covered with the assumption that the students have a fluids background. The amount of material in this book can readily be covered in a one-semester course.

P. Aarne Vesilind
J. Jeffrey Peirce
Ruth F. Weiner

Contents

Chapter 1
Environmental Engineering

Environmental engineering is a new profession with a long and honorable history.

This is not a contradiction. The descriptive title of "environmental engineer" was not used until the 1960s, when academic programs in engineering and public health schools broadened their scope and required a more accurate title to describe their curricula and their graduates. The roots of this profession, however, go back as far as recorded history.

These roots reach into four major disciplines: civil engineering, public health, ecology, and ethics. From each, the environmental engineering profession draws knowledge, skill, professionalism, and concern for the greater good.

CIVIL ENGINEERING

Skills in agriculture spawned the development of a cooperative social fabric and the growth of communities. As farming efficiency increased, a division of labor was possible, and communities began to build permanent public and private structures. Defense of these structures and the land became paramount, and other structures were built purely for defensive purposes. In other societies, the conquest of neighbors also required the construction of machines of war. Builders of these facilities became known as military engineers, and the term engineer continued to imply military involvement well into the eighteenth century.

In 1782, John Smeaton, builder of roads, structures, and canals in England, recognized that since his profession was in the construction of public facilities, he should correctly be designated a *civil* engineer. This title was widely adopted by engineers engaged in public works.[1]

The first engineering curriculum in the United States was established at The United States Military Academy at West Point in 1802. The first engineering course outside the Academy was offered in 1821 at the American Literary, Scientific, and Military Academy, which later became Norwich University. The Rensselaer Polytechnic Institute conferred the first truly *civil* engineering degree in 1835. In 1852, the American Society of Civil Engineers was founded.[2]

Among the public facilities for which the civil engineer became responsible were water supply and wastewater drainage. The availability of water has remained a critical component of civilizations.* Ancient Rome, for example, had water supplied by nine different aqueducts, with cross sections from 2 to 15 m (7 to 50 feet), up to 80 km (50 miles) long.

As cities grew, the demand for water became increasingly acute. In the eighteenth and nineteenth centuries, common people in cities lived under abominable conditions, with water supplies grossly polluted, expensive, or nonexistent.

In London, the water supply was controlled by nine different private companies, and water was sold to the public. Often the poorer people could not afford to pay for the water and begged or stole it. During epidemics, the privation was so great that people went into plowed fields and drank water out of depressions in the ground. Droughts caused water supplies to be curtailed, causing great crowds to form at the public pumps, wanting their "turn" at the pump.[3]

In the New World, the first public water supply system consisted of wooden pipes, bored and charred, with metal rings shrunk on the ends to prevent splitting. The first such pipes were installed in 1652, and the first citywide system was constructed in Winston-Salem, North Carolina, in 1776. The first American water works was built in the Moravian settlement of Bethlehem, Pennsylvania. A wooden waterwheel, driven by the flow of Monocacy Creek, powered wooden pumps that lifted spring water to a wooden reservoir on top of a hill where it was distributed by gravity.[4] One of the first major water supply undertakings was the Croton Aqueduct, started in 1835 and completed six years later. This engineering marvel brought clear water to Manhattan Island, which had an inadequate supply of groundwater.[5]

Although the quantities of water provided by municipal systems might have been adequate, the quality of water was often suspect. As one observer described it:[6]

> The appearance and quality of the public water supply were such that the poor used it for soup, the middle class dyed their clothes in it, and the very rich used it for top-dressing their lawns. Those who drank it filtered it through a ladder, disinfected it with chloride of lime, then lifted out the dangerous germs which survived and killed them with a club in the back yard.

---

*A fascinating account of the importance of water supply to a community through the ages may be found in James Michener's *The Source*.

The earliest known acknowledgment of the effect of impure water is found in *Susruta Samhitta*, a collection of fables and observations on health, dating back to 2000 B.C., which recommended that water be boiled before drinking. The filtration of water became commonplace only toward the middle of the nineteenth century. The first successful filter for water supply was in Parsley, Scotland, in 1804, and many less successful attempts to clarify water by filtration followed.[7] A notable failure was the system for New Orleans, which was to filter water from the Mississippi River. The water proved to be so muddy that the filters clogged up too fast for the system to be workable. This problem was not alleviated until aluminum sulfate (alum) began to be used as a pretreatment. Although the use of alum to clarify water as a pretreatment to filtration was first proposed in 1757, it wasn't until 1885 that this was convincingly demonstrated. Disinfection of water with chlorine was started in 1902 in Belgium and followed in 1908 in Jersey City, New Jersey. The years 1900 to 1920 saw dramatic drops in deaths from infectious diseases, owing in part to the effect of cleaner water supplies.

Human waste disposal in early cities also presented both a nuisance and a serious health problem. Often the method of disposal consisted of nothing more than flinging the contents of chamberpots out the window (Figure 1–1).

Stormwater was considered the main "drainage" problem, and it was in fact illegal in many cities to discharge wastes into the ditches and storm sewers. Eventually, as water supplies developed,* the storm sewers became used for both sanitary waste and stormwater. Such "combined sewers" exist in some of our major cities even today.

The first system for urban drainage in America was constructed in Boston around 1700. There was a surprising amount of resistance to the construction of sewers for waste disposal. Most American cities even at the end of the nineteenth century had cesspools or vaults. The most economical means of waste disposal was to pump these out at regular intervals and cart the waste to a disposal site outside the town. The engineers argued that although sanitary sewers were capital intensive, they provided the best means of wastewater disposal in the long run. Their argument won, and there was a remarkable period of sewer construction between 1890 and 1900.

Actually, the first separate sewerage systems in America were built in the 1880s in Memphis, Tennessee, and Pullman, Illinois. The Memphis system was a complete failure. It used small pipes that were to be flushed periodically. No manholes were constructed, and thus cleanout became a major problem. The system was later removed and larger pipes, with manholes, were installed.[4]

Initially, all sewers emptied into the nearest watercourse, without any treatment. As a result, many of these lakes and rivers became grossly polluted, and as an 1885 Boston Board of Health report put it, "large territories are at

*To hold down the quantity of wastewater discharge, the city of Boston in 1844 passed an ordinance prohibiting the taking of baths without doctor's orders.

Figure 1–1. Human excreta disposal, from an old woodcut. [Source: Reyburn, W. *Flushed with Pride* (London: McDonald, 1969).]

once, and frequently, enveloped in an atmosphere of stench so strong as to arouse the sleeping, terrify the weak and nauseate and exasperate everybody."

Wastewater treatment first consisted only of screening for the removal of the large floatables to protect sewage pumps. Screens had to be cleaned manually, and the wastes were buried or incinerated. The first mechanical screens were installed in Sacramento, California, in 1915, and the first mechanical comminutor for grinding up the screenings was installed in Durham, North Carolina. The first complete treatment systems were operational by the turn of the century, with land spraying of the effluent being a popular method of wastewater disposal.

The engineering for these facilities was the responsibility of the civil engineer, since these were constructed public works. There was, however, little appreciation of the broader perspectives of environmental pollution control and management. These considerations historically have come from the public health professions, from the science of ecology, and perhaps most subtly, from the philosophy of ethics.

PUBLIC HEALTH

Life in cities during the middle ages and through the industrial revolution was difficult, sad, and short. In 1842, the *Report from the Poor Law Commissioners on an Inquiry into the Sanitary Conditions of the Labouring Population of Great Britain* described the sanitary conditions in this manner:

> Many dwellings of the poor are arranged round narrow courts having no other opening to the main street than a narrow covered passage. In these courts there are several occupants, each of whom accumulated a heap. In some cases, each of these heaps is piled up separately in the court, with a general receptacle in the middle for drainage. In others a pit is dug in the middle of the court for the general use of all the occupants. In some the whole courts up to the very doors of the houses were covered with filth.

The great rivers in urbanized areas were in effect open sewers. The River Cam, like the Thames, was for many years grossly polluted. There is a tale of Queen Victoria being shown over Trinity by the Master, Dr. Whewell, and saying, as she looked down over the bridge: "What are all those pieces of paper floating down over the river?" To which, with great presence of mind, he replied: "Those, ma'am, are notices that bathing is forbidden."[8]

During the middle of the nineteenth century, medical knowledge was still primitive, and public health measures were inadequate and often counter-productive. The germ theory was not as yet appreciated, and great epidemics swept over the great cities of the world. Some intuitive measures taken by the public health agencies did, however, have a positive effect. Removal of corpses during epidemics and appeals for cleanliness undoubtedly helped the public health.

The 1850s witnessed what is now called the "Great Sanitary Awakening." Led by tireless public health advocates like Sir Edwin Chadwick, proper and effective measures began to evolve. Possibly the single most important investigation of a public health problem was John Snow's classic epidemiological study of the 1849 cholera epidemic in London. By using a map of the area and identifying the residences of the people who contracted the disease, he was able to pinpoint the cause of the epidemic as the water from a public pump on Broad Street. Removal of the handle from the Broad Street pump eliminated the source of the cholera organism, and the epidemic subsided.* Ever since, waterborne diseases have become one of the major concerns of the public health. The reduction of such diseases by providing safe and pleasing water to the public has been one of the dramatic successes of the public health profession.

*Interestingly, it wasn't until 1884 that Robert Koch proved that *Vibrio comma* was the micro-organism responsible for cholera.