

ENVIRONMENTAL ENGINEERING

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Preface

If any single characteristic can be used to describe environmental engineering, it is that *it is a profession where everything matters*. The natural sciences, the social sciences and the humanities can be just as important in the performance of environmental engineering as the engineering aspects. This fact provides great appeal and challenge for the professional, but also creates an extremely difficult task for authors of a textbook on environmental engineering.

If everything matters, what is to be included in a textbook designed to cover the rudiments of the profession in one semester? We respond to this challenge by organizing the text in five major areas: water resources; air quality; solid and hazardous waste; noise; and environmental impact. We begin by introducing the profession of environmental engineering in its historical context, and finish with a discussion of environmental ethics. There is some justification for introducing the ethical considerations early in the course, and we feel this may be done without loss in continuity. Otherwise, we attempt to carefully introduce concepts and definitions in an orderly manner. If chapters are to stand alone or be taken out of sequence, the instructor should first determine if additional background is needed.

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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 the 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

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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 m to 15 m (7 to 50 ft), up to 80 km (50 mi) 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 city-wide 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 Monococy Creek, powered wooden pumps that lifted spring water to a wooden reservoir on top of a hill where it was distributed by

¹Kirby, R. S., S. Withington, A. B. Darling and F. G. Kilgrou. *Engineering in History* (New York: McGraw-Hill Book Company, 1956).

²Wisely, W. H. *The American Civil Engineer, 1852-1974*, (The American Society of Civil Engineers, New York, 1974).

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

³Ridgeway, J. *The Politics of Ecology*, (E. P. Dutton & Co., 1970).

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.

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 the 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, due in part to the effect of cleaner water supplies.

Human waste disposal in early cities also presented both a nuisance

⁴American Public Works Association. *History of Public Works in the United States 1776-1976* (Chicago: APWA, 1976).

⁵Lankton, L. D. "1842: The Old Croton Aqueduct Brings Water, Rescues Manhattan from Fire, Disease," *Civil Eng.* 47(10) (1977).

⁶Smith, G., *Plague on Us* (Oxford: Oxford University Press, 1941).

⁷Baker, M. N. *The Quest for Pure Water* (New York: American Water Works Association, 1949).

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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).



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

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 which 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 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 pol-

* 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.