Chapter 1

Environmental Engineering

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

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 several major disciplines including:

1. Civil engineering
2. Public health
3. Ecology
4. Chemistry
5. Meteorology.

From each foundation, the environmental engineering profession draws knowledge, skill, and professionalism.

CIVIL ENGINEERING

The development of agricultural skills created a cooperative social structure.

As farming efficiency increased, a division of labor became possible, and communities began to build public and private structures that engineered solutions to specific public problems.

Defense of these structures and of the land became most important, and other structures subsequently were built purely for defensive purposes.

In some societies the construction of war machines are needed.

Builders of war machines became known as engineers.

In 1782 John Smeaton, builder of roads, structures, and canals in England, recognized that his profession tended to focus on the construction of public facilities rather than purely military ones, and that he could correctly be designated a civil engineer.

This title was widely used by engineers engaged in public works.

The first formal university engineering curriculum in the United States was established at the U.S. Military Academy at West Point in 1802.

The **first** engineering course outside the Academy was offered in 1821.

The Renssalaer Polytechnic Institute conferred the first truly civil engineering degree in 1835.

In 1852, the American Society of Civil Engineers was founded.

Water supply and wastewater drainage were among the public facilities designed by civil engineers to control environmental pollution and protect public health.

The availability of water had always been a critical component of civilizations.

Ancient Rome, for example, had water supplied by nine different channels up to 80 km long, with cross sections from 2 to 15 m.

As cities grew, the demand for water increased dramatically.

During the eighteenth and nineteenth centuries the poorer residents of European cities lived under bad conditions, with water supplies that were grossly polluted, expensive, or nonexistent.

In London the water supply was controlled by nine different private companies and water was sold to the public.

People who could not afford to pay for water often begged or stole it.

During epidemics of disease the privation was so great.

In the New World the first public water supply system consisted of wooden pipes 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, NC, in 1776.

The first American water works was built in the Moravian settlement of Bethlehem, PA.

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 BCE, which recommended that water be boiled before drinking.

Water filtration became ordinary toward the middle of the nineteenth century.

The water proved to be so muddy that the filters clogged too fast for the system to be workable.

This problem was not solved until aluminum sulfate (alum) began to be used as a pretreatment to filtration.

The use of alum to clarify water was proposed in 1757, but was not convincingly demonstrated until 1885.

Disinfection of water with chlorine began in Belgium in 1902 and in America in 1908.

Between 1900 and 1920 deaths from infectious disease dropped dramatically, owing in part to the effect of cleaner water supplies.

Human waste disposal in early cities presented a serious health problem.

Often the method of disposal consisted of nothing more than flinging the contents of wastes out the window (Fig. **1-1).**

Around **1550,** King Henri **II** repeatedly tried to get the Parliament of Paris to build sewers, but neither the king nor the parliament proposed to pay for them.

The famous Paris sewer system was built under Napoleon **ID,** in the nineteenth century**.**

Storm water was considered the main "drainage" problem, and it was in fact illegal in many cities to discharge wastes into the ditches and storm sewers.

The first system for urban drainage in America was constructed in Boston around 1700.

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 first separate sewerage systems in America were built in the 1880si n Memphis, TN, and Pullman, **IL.** The Memphis system was a complete failure. It used small pipes that were to be flushed periodically. No manholes were constructed and cleanout became a major problem. The system was later removed and larger pipes, with manholes, were installed.

Wastewater treatment first consisted only of screening for removal of the large floatable to protect sewage pumps.

Screens had to be cleaned manually, and wastes were buried or incinerated.

The first mechanical screens were installed in Sacramento, CA, in 1915, and the first mechanical comminatory for grinding up screenings was installed in **Durham,** NC.

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.

Civil engineers were responsible for developing engineering solutions to these water and wastewater problems of these facilities.

As recently as 1950 raw sewage was dumped into surface waters in the United States, and even streams in public parks and in **U.S.** cities were fouled with untreated wastewater.

PUBLIC HEALTH

Life **in** cites during the middle ages, and through the industrial revolution, was difficult, sad, and usually short.

The great rivers in urbanized areas were in effect open sewers.

During the middle of the nineteenth century, public health measures were inadequate and often counter-productive.

The germ (bacteria and virus) theory of disease was not as yet fully appreciated.
The **1850s** have come to be known as the "Great Sanitary Awakening."

John Snow's classic epidemiological study of the **1849** cholera epidemic in London stands as a seminally important investigation of a public health problem.

By using a map of the area and identifying the residences of those who contracted the disease, John was able to pinpoint the source 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 pathogen, and the epidemic subsided.

Water-borne diseases have become one of the major concerns of the public health. The control of such diseases by providing safe and pleasing water to the public has been one of the dramatic successes of the public health profession.

Today the concerns of public health encompass not only water but all aspects of civilized life, including food, **air,** toxic materials, noise, and other environmental insults.

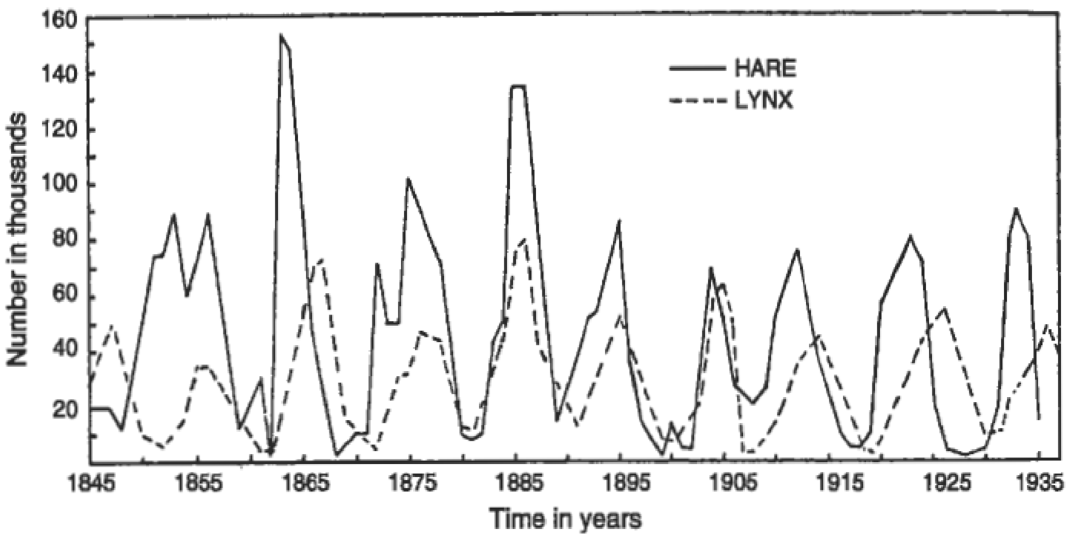
ECOLOGY

The science of ecology defines "ecosystems" as interdependent populations of organisms interacting with their physical and chemical environment.

The populations of the species in an ecosystem do not vary independently but rather fluctuate in an approximate steady state in response ***to*** self-regulating or negative feedback**.**

Homeostatic equilibrium is dynamic, however, because the populations are also governed by positive feedback mechanisms that result from changes in the physical, chemical, and biological environment.

Homeostatic mechanisms can be illustrated by a simple interaction between two populations, such as the hare and the lynx populations pictured in the Fig.



When the hare population is high the lynx have an abundant food supply and procreate.

The lynx population increases until the lynx outstrip the available hare population.

Deprived of adequate food, the lynx population then decreases, while the hare population increases because there **are** fewer predators. This increase, in **turn,** provides more food for the lynx population, and the cycle repeats. The numbers of each population are continually changing, making the system dynamic. When studied over a period of time, the presence of this type of self-regulating feedback makes the system appear to be in a steady state, which we call homeostasis.

In reality, populations rarely achieve steady state for any extended period of time. Instead, populations respond to physical, chemical, and biological changes in the environment.

Some of these changes **are** natural (e.g., a volcanic eruption that covers the lynx and hare habitat with ash or molten rock); many **are** caused by humans (e.g., destruction or alteration of habitat, introduction of competing species, trapping or hunting).

Some ecosystems **are** fragile, easily damaged, and slow to recover; some are resistant to change and are able to withstand even serious perturbations; and others **are** remarkably resilient and able to recover from perturbation if given the chance.

Engineers must consider that threats to ecosystems may differ markedly from threats to public health; for example, acid rain poses a considerable hazard to some lake ecosystems and agricultural products, but virtually no direct hazard to human health.

A converse example is that carcinogens dispersed in the atmospheric environment can enter the human food chain and be inhaled, putting human health at risk, but they could pose no threat to the ecosystems in which they are dispersed.

Engineers must appreciate the fundamental principles of ecology and design in consonance with these principles in order to reduce the adverse impacts on fragile ecosystems. For example, since the deep oceans are among the most fragile of all ecosystems this fragility must be part of any consideration of ocean disposal of waste.

The engineer's job is made even harder when he or she must balance ecosystem damage against potential human health damage. The inclusion of ecological principles in engineering decisions is a major component of the environmental engineering profession.

ETHICS

Historically the engineering profession in general and environmental engineering in particular did not consider the ethical implications of solutions to problems.

Ethics as a framework for making decisions appeared to be irrelevant to engineering since the engineer generally did precisely what the employer or client required.

Today, however, the engineer is no longer free from concern for ethical questions.

Scientists and engineers look at the world objectively with technical tools, but often face questions that demand responses for which technical tools may be insufficient.

In some cases all the alternatives **to** a particular engineering solution include “unethical” elements.

The search for an environmental ethic raises the question of the origin of our attitude toward the environment.

One of the first explicit statements **of** the need for an environmental ethic was penned by Aldo Leopold **(1949).**

Since then, many have contributed thoughtful and well-reasoned arguments toward the development of **a** comprehensive and useful ethic for judging questions of conscience and environmental value.

Since the first Earth Day in **1970** environmental and ecological awareness has been incorporated into public attitudes and is now an integral part of engineering processes and designs.

Today, every news magazine, daily newspaper, and radio and **TV** station in the United States has staff who cover the environment and publish regular environmental features.

Engineers are called on both for project engineering and for assessing the environmental impact of that engineering.

In recent years, and particularly after the accident at the Three Mile Island nuclear plant in 1979, the release of methyl isocyanate at the chemical plant in Bhopal, India, in 1984, and the disastrous nuclear criticality and fire at the Chernobyl nuclear power plant in 1986, general appreciation of the threats to people and ecosystems posed by toxic or polluting substances has increased markedly.

In 1982 the U.S. Environmental Protection Agency @PA) began to develop a system of “risk-based” standards for carcinogenic substances.

It has become difficult to find locations for facilities that can be suspected of producing any toxic, hazardous, or polluting effluent: municipal landfills, radioactive waste sites, sewage treatment plants, or incinerators.

The environmental engineer is cautioned to identify the fine line between real concern about environmental degradation and an almost automatic reaction.

All human activity entails some environmental alteration and some risk, and that a risk-free environment is impossible to achieve.

The balance between risk and benefit to various segments of the population often involves questions of environmental ethics.

ENVIRONMENTAL ENGINEERING AS A PROFESSION

The general mission of colleges and universities is to allow students to mature intellectually and socially and to prepare for careers that are rewarding.

Designing a water treatment facility to provide clean drinking water to a community can serve society and become a personally satisfying undertaking to the environmental engineer.

Environmental engineers now are employed in virtually all heavy industries and utility companies, in any aspect of public works construction and management, by the EPA and other federal agencies, and by the consulting **firms** used by these agencies.

In addition, every governments have agencies dealing with air quality, water quality and water resource management, soil quality, forest and natural resource management, and agricultural management that employ environmental engineers.

Pollution control engineering has also become an exceedingly profitable venture.

Environmental engineering has a proud history and a bright future.

Environmental engineers **are** committed to high standards of interpersonal and environmental ethics.

They **try** to be part of the solution while recognizing that all people including themselves are part of the problem.