CIVE 3331 - ENVIRONMENTAL ENGINEERING

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Environmental Engineering

What is "environmental engineering?"

Environmental engineering is the development and implementation of processes, structures, and administrative procedures to supply drinking water, dispose of waste materials, maintain air quality, and control pollution of all kinds. Environmental engineering protects public health by prevention of disease transmission; it protects public resources by averting contamination and degradation of air, water, and land.

What kind of things do "environmental engineers do?"

A brief listing of the kinds of projects environmental engineers contribute to includes:

- Capture, treatment, and distribution of drinking water.
- Collection, treatment, discharge of wastewater.
- Characterization, control, reduction of air pollutants.
- Characterization, control, reduction of noise pollution.
- Characterization, control, reduction of thermal pollution.
- Collection, treatment, storage of solid waste.
- Collection, treatment, storage of hazardous waste.
- Restoration of contaminated soil, water, and air.
- Preparation of, monitoring for, compliance with discharge permits.
- Assessment, audits, and impact studies.
- Preparation of legislation; drafting of environmental regulations.

Historical Evolution of Environmental Engineering.

Environmental engineering has emerged as a distinct discipline (at least with that name) relatively recently; the discipline has a long history of practice. Much of the early history targeted human wastes following the "sanitation theory" of disease transmission. Water quality has been a concern even longer with evidence that in 2000 B.C. water was purified by boiling and filtration. The ancient Romans left behind ruins of an extensive aqueduct system that is a testament to the importance of both a sufficient quantity (volume) and quality of water. Roman ruins also have sophisticated wastewater collection and transmission systems. In ancient times, toilets were harvested for urea (a component of urine) that is used in dye making and other early industries. In the mid-nineteenth century, the field of sanitary engineering emerged with the specific mission to provide clean drinking water and to collect, treat, and appropriately dispose of wastewater.

Air pollution also has a long history – at least to the seventeenth century. The source of air pollution in the past was poorly controlled combustion of low-quality fuels, such as sulfur-rich coal, for light industry, domestic heating, and cooking. Despite early recognition of the problem, little was done until the 1950's. Much of the world still suffers from severe air pollution caused by combustion of low-quality fuels – especially in the developing nations where exposure to biomass cooking fuels is common. In these stoves, there is often no flue or vent and the combustion gasses mix with air in the living space.

In the United States and other developed nations, the 1970's was the beginning of an enormous effort to improve environmental quality in response to increasing public awareness and concern of the preceding few decades. In the USA this concern was expressed politically by the creation of the cabinet level agency, the U.S. Environmental Protection Agency. Technological advances funded through this agency other federal agencies, and industrial advocacy organizations (API, EPRI, GRI etc.) have generated much of the evolutionary changes in sanitary engineering that is now called environmental engineering.

Table 1 lists some approximate dates of important environmental engineering advances. The table also lists major military conflicts. The inclusion of military history is significant because much of the technological advances in water quality were a direct response to the need to maintain healthy troops in various locations – Chlorine, a war gas, revolutionized drinking water treatment and undoubtedly has saved hundreds of millions of people from exposure to waterborne disease. In my opinion it is the single most important public health chemical of the 20th century, closely followed by DDT (now illegal in the USA), and penicillin.

Table 1. Important dates in Environmental Engineering (USA)

Other Historical Events	Date	Item
	1820's	Storm sewer and sanitary sewer systems
	1830's	Design of water supply systems
	1800-1850's	"Era of hydraulic engineering advancements"
Civil War Era	1850	Recognition of pollution of water sources by sanitary sewers.
	1854	Dr. Snow identifies cholera source in London - Epidemiology applied to public health.
	1870	"Sanitary chemistry"
	1890	Sand filtration, trickling filters - Treatment
	1891	Epidemiology identifies typhoid as waterborne disease
	1893	Sedimentation - Treatment
	1900	Activated sludge - Treatment
	1901	U.S. PHS Hygiene Laboratory created – later merged into CDC
WWI	1913	U.S. PHS Cincinnati Laboratory
	1918	Activated sludge in Houston, TX -First large-scale application
	1923	**Chlorine disinfection - Treatment**
WWII & Korea	1944	Donora, PA - 1st large scale air pollution event in USA that killed people.
	1948	Water Pollution Control Act
USA in Vietnam	1964	"Silent Spring" by Rachael Carson -Popular novel published that is a political focal point for concerned citizens in USA.
	1969	National Environmental Protection Act
	1970	"Earth Day" -Popular demonstration that served as political focal point for concerned citizens in USA.
	1970	Creation of U.S. Environmental Protection Agency
	1972	Clean Water Act
	1976	Resource Conservation and Recovery Act (RCRA) - Hazardous materials
	1980	CERCLA
	1990	Clean Air Act Amendments

Policy and Legislation

Most environmental engineering activities are motivated by environmental regulations; consequently an understanding of policy and legislative interactions is crucial to environmental engineering activities. Release of pollutants into the environment is inevitable, and contaminants in air and water cannot be avoided. Even pristine environments contain chemicals and organisms that are harmful to humans. Society cannot make a decision about whether there should be pollutants or not, but can only decide what levels of pollution are acceptable. These decisions are to be based on health effects and other costs of the pollutant and on technology to control the pollutant. The policy problem is complicated because the information on health effects is incomplete, uncertain, and conflicting; the costs are difficult to quantify; the political system is structured so that special interests can influence the decision. Despite these difficulties regulations exist at the federal and state levels (USA) to address water quality, air quality, and hazardous waste. The need for regulations at all is explained in

Concept of common or shared resource.

Legislation (laws) are important in environmental engineering because the environment is a shared resource. The concept of a shared resource is “classically” explained in a agricultural context.

Consider a single large pasture that is open to all herdsmen. Since the proceeds of the sale of cattle go entirely to the herdsman adding another cow to the pasture produces a utility to the herdsman of nearly 1-unit. The additional cow slightly reduces the quality of the pasture for all the cows, but the individual herdsman shares this deficit with other herdsmen. That is his one additional cow produces a negative utility that is a fraction (f) of minus 1-unit. The net utility of an additional cow is $1 + (-f) > 0$ thus the herdsman chooses to add an additional cow. But every herdsman comes to the same conclusion and eventually there are enough cattle added to the pasture so that the fractional negative utilities are significant and none of the cattle survive to reach market.

Another way to explain the concept in terms more relevant to urban dwellers is to use automotive emissions as the example. Suppose there are 2 million cars in an urban area and 5 million people. Assume the air is completely mixed throughout the air basin. Suppose it costs $500 per automobile for a good emission control system. Assume that <u>each</u> emission control system produces a health benefit for each resident of $0.01 (one cent per resident) over the life of the car. Would an individual voluntarily install such a system? Probably not, the direct benefit to the individual is only a few cents (the driver and his family), but the $500 cost is a real and immediate cost. The rational individual would conclude that the cost far outweighs the benefit. However the benefit to society (the 5 million residents) is substantial, about $50,000/automobile. Thus it is wise for society in this example to require each individual to pay for the cost of control.

This incentive to oversubscribe to a resource is called the "tragedy of the commons." It is fundamental to why environmental laws exist. Air, water, and soil (to some extent) are shared resources that must be manages so that there will be enough resources for all to survive. In the case of environmental quality, although each individual can profit by avoiding the expense of proper waste management, that profit is gained at the expense of damaging the quality of the environment, however slightly, for everyone that shares it. When these small damages are accumulated (integrated) over the enormous number of individuals, the cumulative negative consequences can be much larger than the individual gains.

Legislation is a way to allocate the resources by a variety of techniques: lottery, auction, first-come first-served; permits; etc.

How legislation is created (in USA).

U.S. Congress writes laws. Once the laws are passed (by executive approval) then congress directs the appropriate agency (that usually reports to the president) to develop and publish regulations to implement the law.

Laws are typically reactive: hazardous materials produced in the 1940's were not closely regulated until the 1970's when their effects became apparent.

Monitoring and Enforcement.

Environmental laws are typically enforced by the U.S. EPA and equivalent state agencies. Some local jurisdictions have environmental enforcement divisions (the Houston Police Department is an example) to enforce environmental regulations that have immediate health and safety impact. In addition most health departments have enforcement authority and routinely issue citations for violation of environmental laws. For large operations much of the enforcement is based on self-reporting with regulatory oversight.

Federal

U.S. EPA was created in 1970. It was charged with multiple missions: establish standards protective of the environment and consistent with U.S. goals; conduct research on pollutant effects and treatments; provide financial and technical assistance; assist the CEQ in recommendations to the President regarding environmental policy.

State

State agencies are typically modeled on the U.S. EPA organizational and mission structure. They enforce state laws, and if state laws are equal to or more strict than federal laws, then the state agency can be designated to enforce specific federal laws. In Texas, the TCEQ (Texas Commission on Environmental Quality) is the state agency. It is a designee agency for most federal water quality laws and the NPDES (National Pollutant Discharge Elimination System) permitting program.

Local (County, City)

Local jurisdictions usually enforce ordinances (city laws) that may be "environmental laws." Typically local issues deal with quality of life issues (aesthetics, nuisance odors, etc.). In Houston, the local jurisdictions that have some enforcement capability are the HPD Environmental Enforcement Division (illegal dumping; illegal transport of hazardous materials, etc.) and the DHHS (Department of Health and Human Services)(un-permitted discharges to storm water; illegal storage of garbage; etc.).

Enforcement Methods

Majority of discharges are self-reporting. This model of enforcement is much different than governmental monitoring and risk of apprehension. Primary reason for this enforcement approach is economics. Selected governmental and citizen monitoring has impact and helps ensure compliance. Malicious polluting is a criminal act; accidental discharge or exceeding permitted levels because of equipment failure (as long as diligence in repair can be documented) is a civil offence. The penalties vary (criminal acts can result in jail time), but are sufficiently expensive so that dischargers have an incentive to meet their permits. Really large corporations can easily afford the penalties, but public relations considerations go a long way to ensure compliance.

Effluent Standards

An effluent standard is based on the quantity of material released into the environment (end-of-pipe). It is easy to monitor. It is consistent in that a polluter must comply with a certain allowable level of pollutant masses and volumes.

Receiving Medium Standards

A receiving medium standard is based on the quality of the medium into which the pollutant is to be placed. A discharger can discharge any amount of pollutant as long as it does not cause the receiving medium quality to fall below some established minimum value (for that pollutant). This standard allows for flexible discharge patterns to take advantage of variations in natural assimilative capacity. Enforcement (in the US legal system) is difficult; dischargers must have highly trained personnel effective real-time monitoring to take advantage of this type of standard.

In most cases in the USA effluent based standards are the norm. Receiving medium standards are established and monitored to determine if unregulated discharges are occurring and if the effluent standards are effective.

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