Chapter 22

WATER POLLUTION AND TREATMENT

Case Study: What is the Value of Clean Water to New York city?

● Coastal North Carolina is a region with an industrial-scale swine industry. As in any large-scale husbandry operation, an enormous amount of animal waste is generated and must be disposed of. The practice in North Carolina is to keep the waste in large lagoons. The contents of these waste lagoons leak into the ground water, and occasionally there are failures of the earthen dams or retaining walls surrounding these lagoons. When the retention wall fails, there is often an episodic release of concentrated waste into nearby streams and rivers. Hurricanes have also caused widespread failures of waste lagoons. In recent years there have been outbreaks of toxic dynoflagellates (a type of algae) in NC rivers and estuaries that have been linked to massive fish kills. Though the direct cause of the fish kills remains controversial (dynoflagellate vs hypoxia), there is consensus that water quality in NC is in trouble.

22.1 Water Pollution

● Obtaining clean, disease-free water for drinking is the major health problem facing most humans. Pollution of surface and ground water occurs in many ways from numerous sources (see Table 22.1). Generally the sources are pollution can be categorized as either point-source or non-point source pollutants. Point-source pollutants are theoretically most easy to deal with, because one can collect the pollutants at the point of discharge and treat them.

22.2 Biochemical Oxygen Demand (BOD)

● BOD is a measure of the amount of oxygen consumed by microorganisms in water in a fixed amount of time, typically 5 days (BOD5). BOD is caused by the respiration of bacteria that are consuming organic matter. Thus, BOD is related to the organic matter in the water. When BOD is high, the oxygen concentration in the water can be reduced to levels that are too low for many fish species and other organisms. High BOD is a frequent cause of fish kills. High BOD can happen because of a rapid "bloom" of algae caused by nutrients. The high BOD happens when the algae die in mass. Or BOD can happen because organics (e.g. blood from a meat packing factory) or dumped into a river directly, which leads to a zone of low oxygen (see Fig. 22.3).

22.3 Waterborne Disease

● The importance of waterborne disease has been recognized for well over a century, since a cholera outbreak in London was traced to a public well on Broad Street in 1854. The generic term for waterborne disease is ‘toilet to mouth’ disease, because of the mode of infection. Waterborne disease is common in undeveloped nations, where water

treatment is not advanced, and even in the United States occasional outbreaks are not unknown. In 1993 there was an outbreak of *Cryptosporidium* in drinking water that affected 400,000 people in Milwaukee. It is difficult to test for and monitor the multitude of disease organisms (ranging from viruses to protozoans), but an easy and relatively quick test of fecal contamination is available. This is the **fecal coliform** test. Fecal coliforms (specifically *E. coli*) are bacteria that live in the digestive system. When they are detected in water, then there is a possibility that disease organisms spread through fecal matter are also present. Standards are used that recognize different levels of hazard depending on the concentrations of coliforms. Drinking water standards are most strict, ranging up to concentrations at which boating is not allowed. One significant problem with this test is that it does not distinguish between coliforms from humans and other vertebrate animals.

22.4 Nutrients

● N and P are most important; fertilizers and sewage effluent (incl. Detergent) are rich sources. Nutrient levels can reach such high levels that algal populations explode. As the algal populations crash, the decomposition of their remains robs the water of oxygen (high BOD), resulting in fish kills. Thus the N&P are not directly toxic, but cause a cascade of effects that end in mortality. The technical term for this entire syndrome is **eutrophication (**see Fig. 22.7). Eutrophication is a natural process, normally very slow. The term **cultural eutrophication** describes the accelerated process caused by people. The solution to cultural eutrophication is to prevent excessive nutrient loadings. This is more easily accomplished when dealing with **point sources** (see 22.13) of nutrients.

A Closer Look 22.1: Cultural Eutrophication in the Gulf of Mexico

● At the mouth of the Mississippi River (MR) in the Gulf of Mexico there is a large area, referred to as the dead zone, where oxygen concentrations are low enough to cause fish kills. The MR drainage basin encompasses about 1/3 of the continental U.S. and drains majors agricultural areas and major cities. A number of scientists (e.g. Rablais, Turner) have collected evidence that strongly suggests that the agricultural chemicals (mainly fertilizers) are responsible for the dead zone. This is extremely controversial and the farm industry is refuting this evidence for fear that the federal government will legislate restrictions on how farmers can manage their lands.

22.5 Oil

● Oil is discharged into water from bilge water from tankers, from oil spills, and from the runoff from roadways, which collect the oil leaks from our vehicles. The best known oil spill was caused by the grounding of the oil tanker Exxon Valdez in Prince William Sound, Alaska- one of the most pristine marine environments in the world. The spilled oil, 11 million gallons, killed 13% of the harbor seals, 28% of the otters, and 100,000-645,000 sea birds. The volatile fractions of oil are highly toxic and will cause cancer. Only about 14% of the spilled oil was recovered. Fortunately the oil is biodegradable, but the long term effects are unknown.

22.6 Sediment

● Sediment eroding from agricultural landscapes and construction sites is another serious pollution problem. Excessive sediment loads can easily smoother the benthic fauna and flora (incl. submerged aquatic vegetation) in a stream or lake. Construction sites now must use erosion controls around their sites to reduce the impact. The erosion from fields can be reduced by using no-till agriculture and other means, and buffer zones of natural vegetation around streams can reduce the sediment as well as the nutrient loads.

22.7 Acid Mine Drainage

● AMD occurs when precipitation percolates through mine tailings rich in sulfidic minerals such as pyrite. The sulfides are oxidized by oxygen in the water or air to produce sulfuric acid (H_2SO_4). The acid water then drains into nearby lakes and streams. The effects on local ecosystems can be severe.

22.8 Surface-Water Pollution

● May occur from both point and non-point sources. In the U.S. and other developed nations there is a growing list of success stories about rivers that have been greatly improved by implementing pollution control of point sources. The Potomac River was once so polluted that is was dangerous to swim in. The Cuyahoga R. in Cleveland, which ignited in flames in 1969, is no longer flammable. Today in the U.S., nonpoint sources of pollutions, particularly from agriculture, are the major water quality problems.

22.9 Groundwater Pollution

● About ½ of the people in the U.S. depend on ground water as a source of drinking water. Ground water has a low turnover time. Thus, pollution of ground water is difficult to rectify when it occurs. Contamination of ground water by toxic chemicals typically must be cleaned by a pump and treat process that is expensive and time consuming. **Bioremediation** is also used, either in conjunction with pump and treat, or by directly injecting nutrients into the ground water that would stimulate microbes to consume the toxins. This is often effective when the pollutants are organic toxins that microbes can degrade.

A Closer Look 22.2: Water for Domestic Use: How Safe is it?

● Domestic water in the U.S. is either drawn from surface or ground water, depending on location. The water is first treated by chlorination, and sometimes with fluorine, and stored in a reservoir before distribution. Biologically the water is safe, though there have been rare instances of outbreaks of pathogens. The greatest concerns are taste, which is not a health issue, and with trace contaminants (toxic organics and heavy metals). The pipes in homes can be a source of lead pollution. Also, the chlorine can react with dissolved organic matter to create chlorinated hydrocarbons that are suspected of causing cancer. This requires more research. In the meantime, people are opting to consume more bottled water, currently selling for more than the price of oil. Home treatment systems (activated charcoal filters) are effective in removing the organics and heavy metals, but the filters need to be routinely changed because they can become colonized by bacteria and lose their effectiveness over time.

22.10 Wastewater Treatment

● Water Treatment- describe how water is treated for drinking (note that the first treatment of drinking water began in 1872 with sand filtration- this method is fairly good at removing bacteria; chlorination began in 1902 and is effective against most pathogens.

● Treatment of Waste (see Fig. 22.19)- describe primary treatment, which removes solids that settle in a tank; secondary treatment, which is a biological process that removes much of the dissolved organic matter and BOD, and some of the nitrogen via denitrification; and tertiary treatment, which is a chemical process that removes the inorganic nutrients, especially phosphorus. Note that at the secondary treatment step, bacteria convert the organics to inorganics. Also note that tertiary treatment is still rarely practiced. It is expensive.

● In home treatment of waste is practiced in some countries using a device called a Clivus multrum. This is basically an outhouse. The waste accumulates in a holding bin, it is composted there and makes a rich fertilizer. Modern design and ventilation prevent bad smell.

● Septic tanks are another from of home waste treatment. The waste flows into a tank where the solids settle, and the liquid flows into a leach field. The grass is normally greener over the leach field! There are usually regulations about where septic tanks can be used and their design. Periodically they must be cleaned, and this is accomplished by a commercial service, euphemistically called a honey wagon, that sends out a truck to pump out the tank. Septic tanks are common in rural or outlying suburban areas where the population density is low. They can cause problems when used around lakes and streams because of the leachate.

● A problem that faces many wastewater systems is the effect of storm water runoff. Sewers often pick up storm water, which raises the volume of water entering the plant. After a big storm, under these conditions raw sewage can pour into the river. In New Haven, CT for example, after a rain storm you would find corn all over the mud flats in the harbor (the corn is undigested waste from the sewage treatment plant, the birds loved it).

● There is a waste disposal problem with the solids collected at the waste treatment plant as well as a problem with contamination of the solid waste with toxic contaminants. The sludge is commonly composted, spread on fields, given to farmers, etc.

● Discuss the multitude of toxins that enter the waste stream (used motor oil, heavy metals, paint solvents, pharmaceuticals that include mercury compounds, in short everything that anyone disposes of down the drain or in some cases down the storm sewer)

22.11 Land Application of Wastewater

● is yet another method of treating domestic wastewater. This is practiced in some areas of the U.S. and is the common means of water treatment in Dutch cities and elsewhere.

In theory it is a method of recycling the waste and nutrients back into an ecosystem, such as an agricultural ecosystem. In The Netherlands waste water is pumped into sand dunes where a natural filtering and biological treatment occurs, and the water is recycled back into the ground water which is used for human consumption. In rural China the waste is often used to generate methane, which is used for cooking, and is recycled back onto the agricultural fields from which the nutrients originated.

A Closer Look 22.3: Boston Harbor: Cleaning up a National Treasure

Boston Harbor disposes of its treated waste water by piping it onto the harbor. The waste is secondary effluent, contaminated episodically by raw sewage during storms. The water quality of the harbor deteriorated until the outfalls were relocated further offshore. The harbor is now rebounding, but this solution may not be an adequate long-term solution.

22.12 Water Reuse

● Inadvertent water reuse is common and occurs when water is withdrawn, used, treated and returned to the source where subsequent use is possible, as when water is taken from a river by a municipality and returned, only to be used again by a city downstream. There are risks.
● Indirect reuse is planned, as when wastewater is treated and recycled back into the source water for reuse.
● Direct reuse occurs when treated wastewater is piped directly from a treatment plant to the next user. There is little direct reuse of water for human consumption. Mostly this is used for other purposes such as watering golf courses. Waste water from the home from the laundry and sinks, termed grey water, can be used for watering lawns or washing cars.

22.13 Water Pollution and Environmental Law

● Although a federal law designed to protect water resources is as old as 1899, prior to 1974 there were no enforceable national standards for drinking water. In 1974 the Drinking Water Act was passed. This law required the EPA to establish standards, called maximum contaminant levels, for any pollutant that may have adverse effects on human health. They have been slow, by 1986 the EPA had set maximum contaminant levels for 26 out of 700 potential toxins. See table 22.4.

Critical Thinking Issues

● Regulation of land use
Assume that the evidence is unequivocal that the dead zone at the mouth of the Mississippi River is caused by fertilizer applied to fields in the drainage basin, the heart of the U.S. gain belt. Should the federal government move to regulate the use of farm chemicals in order to improve water quality? What are the costs and benefits? Does the federal government have jurisdiction?

● How can polluted waters be restored?

Refer to Table 22.5, which gives a history of the events related to water quality in the Illinois River, and explain changes in fisheries production and water quality.

Web Resources

http://www.ph.ucla.edu/epi/snow.html A neat site at UCLA devoted to the life and times of Dr. John Snow who was the father of epidemiology.