

Chapter 4

Water Pollution

Although people intuitively relate filth to disease, the transmission of disease by pathogenic organisms in polluted water was not recognized until the middle of the nineteenth century. The Broad Street pump handle incident demonstrated dramatically that water could carry diseases.

In 1854, a public health physician named John Snow, assigned to try to control the spread of cholera, noticed a curious concentration of cholera cases in one part of London. Almost all of the people affected drew their drinking water from a community pump in the middle of Broad Street. However, people who worked in an adjacent brewery were not affected. Snow recognized that the brewery workers' apparent immunity to cholera occurred because the brewery drew its water from a private well and not from the Broad Street pump (although the immunity might have been thought due to the health benefits of beer). Snow's evidence convinced the city council to ban the polluted water supply, which was done by removing the pump handle so that the pump was effectively unusable. The source of infection was cut off, the cholera epidemic subsided, and the public began to understand the importance of having clean drinking water supplies.

Until recently, water pollution was viewed primarily as a threat to human health because of the transmission of bacterial and viral waterborne diseases. In less developed countries, and in almost any country in time of war, waterborne diseases remain a major public health threat. In the United States and other developed countries, however, water treatment and distribution methods have almost eradicated microbial contamination in drinking water. We now recognize that water pollution constitutes a much broader threat and continues to pose serious health risks to the public as well as aquatic life. In this chapter we discuss the sources of water pollution and the effect of this pollution on streams, lakes and oceans.

SOURCES OF WATER POLLUTION

Water pollutants are categorized as *point source* or *nonpoint source*, the former being identified as all dry weather pollutants that enter watercourses through pipes or channels. Storm drainage, even though the water may enter watercourses by way of pipes or channels, is considered nonpoint source pollution. Other nonpoint source pollution comes from agricultural runoff, construction sites, and other land disturbances,

as discussed in Chap. 11. Point source pollution comes mainly from industrial facilities and municipal wastewater treatment plants. The range of pollutants is vast, depending only on what gets “thrown down the drain.”

Oxygen demanding substances such as might be discharged from milk processing plants, breweries, or paper mills, as well as municipal wastewater treatment plants, compose one of the most important types of pollutants because these materials decompose in the watercourse and can deplete the water of dissolved oxygen.

Sediments and suspended solids may also be classified as a pollutant. Sediments consists of mostly inorganic material washed into a stream as a result of land cultivation, construction, demolition, and mining operations. Sediments interfere with fish spawning because they can cover gravel beds and block light penetration, making food harder to find. Sediments can also damage gill structures directly, smothering aquatic insects and fishes. Organic sediments can deplete the water of oxygen, creating anaerobic (without oxygen) conditions, and may create unsightly conditions and cause unpleasant odors.

Nutrients, mainly nitrogen and phosphorus, can promote accelerated eutrophication, or the rapid biological “aging” of lakes, streams, and estuaries. Phosphorus and nitrogen are common pollutants in residential and agricultural runoff, and are usually associated with plant debris, animal wastes, or fertilizer. Phosphorus and nitrogen are also common pollutants in municipal wastewater discharges, even if the wastewater has received conventional treatment. Phosphorus adheres to inorganic sediments and is transported with sediments in storm runoff. Nitrogen tends to move with organic matter or is leached from soils and moves with groundwater.

Heat may be classified as a water pollutant when it is caused by heated industrial effluents or from *anthropogenic* (human) alterations of stream bank vegetation that increase the stream temperatures due to solar radiation. Heated discharges may drastically alter the ecology of a stream or lake. Although localized heating can have beneficial effects like freeing harbors from ice, the ecological effects are generally deleterious. Heated effluents lower the solubility of oxygen in the water because gas solubility in water is inversely proportional to temperature, thereby reducing the amount of dissolved oxygen available to *aerobic* (oxygen-dependent) species. Heat also increases the metabolic rate of aquatic organisms (unless the water temperature gets too high and kills the organism), which further reduces the amount of dissolved oxygen because respiration increases.

Municipal wastewater often contains high concentrations of organic carbon, phosphorus, and nitrogen, and may contain pesticides, toxic chemicals, salts, inorganic solids (e.g., silt), and pathogenic bacteria and viruses. A century ago, most discharges from municipalities received no treatment whatsoever. Since that time, the population and the pollution contributed by municipal discharge have both increased, but treatment has increased also.

We define a population equivalent of municipal discharge as equivalent of the amount of untreated discharge contributed by a given number of people. For example, if a community of 20,000 people has 50% effective sewage treatment, the population equivalent is $0.5 \times 20,000$ or 10,000. Similarly, if each individual contributes 0.2 lb of solids per day into wastewater, and an industry discharges 1,000 lb/day, the industry

has a population equivalent of 1,000/0.2, or 5,000. The current estimate of the population equivalent of municipal discharges into U.S. surface water is about 100 million, for a population of nearly 300 million. The contribution of municipal discharges to water pollution has not decreased significantly in the past several decades, nor has it significantly increased; at least we are not falling behind.

The sewerage systems in older U.S. cities have aggravated the wastewater discharge situation. When these cities were first built, engineers realized that sewers were necessary to carry off both storm water and sanitary wastes, and they usually designed a single system to carry both discharges to the nearest appropriate body of water. Such systems are known as combined sewers.

Almost all of the cities with combined sewers have treatment plants that can only handle dry weather flow (i.e., no storm water runoff). When it rains, the flow in the combined sewer system increases to many times the dry weather flow and most of it must be bypassed directly into a river, lake, or bay. The overflow will contain raw sewage as well as storm water, and can be a significant pollutant to the receiving water. Attempts to capture and store the excess flow for subsequent treatment are expensive, and the cost of separating combined sewer systems may be prohibitive.

As years passed, city populations increased, and the need for sewage treatment became apparent. Separate sewer systems were built: one system to carry sanitary sewage to the treatment facility and the other to carry storm water runoff. This change improved the overall treatment of sewage by decreasing the frequency of bypasses and allowing additional levels of sewage treatment, such as phosphorus removal, to be added at the wastewater treatment plant. It left unresolved the treatment of storm water runoff, which is now one of the major sources of water pollution in the United States.

Agricultural wastes that flow directly into surface waters have a collective population equivalent of about two billion. Agricultural wastes are typically high in nutrients (phosphorus and nitrogen), biodegradable organic carbon, pesticide residues, and *fecal coliform* bacteria (bacteria that normally live in the intestinal tract of warm-blooded animals and indicate contamination by animal wastes). Feedlots where large numbers of animals are penned into relatively small spaces provide an efficient way to raise animals for food. They are usually located near slaughterhouses, and thus near cities. Feedlot drainage (and drainage from intensive poultry cultivation) creates an extremely high potential for water pollution. Aquaculture has a similar problem because wastes are concentrated in a relatively small space. Even relatively low densities of animals can significantly degrade water quality if the animals are allowed to trample the stream bank, or runoff from manure-holding ponds is allowed to overflow into nearby waterways. Both surface and groundwater pollution are common in agricultural regions because of the extensiveness of fertilizer and pesticide application.

Pollution from petroleum compounds ("oil pollution") first came to public attention with the Torrey Canyon disaster in 1967. The huge tanker loaded with crude oil plowed into a reef in the English Channel. Despite British and French attempts to burn the oil, almost all of it leaked out and fouled French and English beaches. Eventually, straw was used to soak up the oil and detergents were applied to disperse the oil (detergents were later found to be harmful to the coastal ecology).

By far the most notorious recent incident has been the *Exxon Valdez* spill in Prince William Sound in Alaska. Oil in Alaska is produced in the Prudhoe Bay region in northern Alaska and piped down to the tanker terminal in Valdez on the southern coast. On March 24, 1989, the *Exxon Valdez*, a huge oil tanker loaded with crude oil veered off course and hit a submerged reef, spilling about 11 million gallons of oil, into Prince William Sound. The effect was devastating to the fragile ecology. About 40,000 birds died, including about 150 bald eagles. The final toll on wildlife will never be known, but the effect of the spill on the local fishing economy can be calculated and it exceeds \$100 million. The cleanup by Exxon cost at least \$2 billion, and the legal responsibility is still being debated.

While oil spills as large as the *Exxon Valdez* spill get a lot of publicity, it is estimated that there are about 10,000 serious oil spills in the United States every year, and many more minor spills from routine operations that do not make headlines. The effect of some of these spills may never be known. In addition to oil spills, petroleum hydrocarbons from atmospheric sources (e.g., automobile exhaust fumes) are deposited daily on road surfaces. When it rains, these oily deposits wash into nearby streams and lakes.

The acute effect of oil on birds, fish, and other aquatic organisms is well cataloged; the subtle effects of oil on aquatic life is not so well understood and is potentially more harmful. For example, anadromous fish that find their home stream by the smell or taste of the water can become so confused by the presence of strange hydrocarbons that they will refuse to enter their spawning stream.

Acids and bases from industrial and mining activities can alter the water quality in a stream or lake to the extent that it kills the aquatic organisms living there, or prevents them from reproducing. Acid mine drainage has polluted surface waters since the beginning of ore mining. Sulfur-laden water leached from mines, including old and abandoned mines as well as active ones, contains compounds that oxidize to sulfuric acid on contact with air. Deposition of atmospheric acids originating in industrial regions has caused lake acidification throughout vast areas of Canada, Europe, and Scandinavia.

Synthetic organics and *pesticides* can adversely affect aquatic ecosystems as well as making the water unusable for human contact or consumption. These compounds may come from point source industrial effluents or from nonpoint source agricultural and urban runoff.

The effects of water pollution can be best understood in the context of an aquatic ecosystem, by studying one or more specific interactions of pollutants with that ecosystem.

ELEMENTS OF AQUATIC ECOLOGY

Plants and animals in their physical and chemical environment make up an *ecosystem*. The study of ecosystems is termed *ecology*. Although we often draw lines around a specific ecosystem to be able to study it more fully (e.g., a farm pond) and thereby assume that the system is completely self-contained, this is obviously not true. One of the tenets of ecology is that “everything is connected with everything else.”