there are limits to what soil can remove, and groundwater pollution is becoming an increasing concern throughout the world.

Many soils do have the ability to remove certain types of pollutants, including phosphorus, heavy metals, bacteria, and suspended solids. Pollutants that dissolve in water, like nitrate and ammonia, may pass through soils into the groundwater. In agricultural regions, the nitrogen and other soluble chemicals in fertilizers or animal wastes can seep into the groundwater and show up in alarmingly high concentrations in local drinking water wells. A recent study of the Abbotsford/Sumas aquifer (a water-bearing zone of rock, sand, gravel, etc.), which supplies water to more than 100,000 people in the western portion of Canada and Washington, indicated that 40% of the wells tested had nitrate levels above 10 mg/L (EPA maximum recommended drinking water level), and 60% had nitrate levels above 3 mg/L (a general warning level for nitrate in drinking water).

The agricultural community is becoming more aware of the connection between agricultural practices and groundwater pollution. Many states have begun working with dairy owners and farmers to develop farm management plans that restrict fertilizer applications to periods of active plant growth, which helps prevent groundwater pollution by sequestering nitrate into growing vegetation. These farm plans also include surface water pollution prevention techniques such as restricting animal access to stream banks, setting maximum animal density goals, requiring manure-holding ponds, and revegetating *riparian* (stream side) areas.

Other potential sources of groundwater pollution include leaking underground storage tanks, solid waste landfills, improperly stored hazardous waste, careless disposal of solvents and hazardous chemicals on ground surfaces, and road salts and deicing compounds. Many of the current U.S. Superfund sites (see Chap. 17, "Solid and Hazardous Waste Law") are concerned with the cleanup of materials that have contaminated, or have the potential to contaminate, groundwater.

## EFFECT OF POLLUTION ON OCEANS

Not many years ago, the oceans were considered infinite sinks; the immensity of the seas and oceans seemed impervious to assault. Now we know that the seas and oceans are fragile environments and we are able to measure detrimental effects.

Ocean water is a complicated chemical solution, and appears to have changed very little over millions of years. Because of this constancy, however, marine organisms have become specialized and intolerant to environmental change. Oceans are thus fragile ecosystems, quite susceptible to pollution.

A relief map of the ocean bottom reveals two major areas: the continental shelf and the deep oceans. The continental shelf, especially near major estuaries, is the most productive in terms of food supply. Because of its proximity to human activity, it receives the greatest pollution load. Many estuaries have become so badly polluted that they are closed to commercial fishing. The Baltic and Mediterranean Seas are in danger of becoming permanently damaged.

Ocean disposal of untreated wastewater is severely restricted in the United States, but many major cities all over the world still discharge untreated sewage into the ocean. Although the sewage is carried a considerable distance from shore by pipeline and discharged through diffusers to achieve maximum dilution, the practice remains controversial, and the long-term consequences are much in doubt. Even in the United States, most sewage effluents receive only secondary treatment (see Chap. 7, "Water Treatment"), which is not effective at removing certain types of pollutants, including phosphorus.

## HEAVY METALS AND TOXIC SUBSTANCES

In 1970, Barry Commoner (Commoner 1970) and other scientists alerted the nation to the growing problem of mercury contamination of lakes, streams, and marine waters. The manufacture of chlorine and lye from brine, called the chlor-alkali process, was identified as a major source of mercury contamination. Elemental mercury is methylated by aquatic organisms (usually anaerobic bacteria), and methylated mercury finds its way into fish and shellfish and thus into the human food chain. Methylmercury is a powerful neurological poison. Methylmercury poisoning was first identified in Japan in the 1950s as "Minamata disease." Mercury-containing effluent from the Minamata Chemical Company was found to be the source of mercury in food fish. Mercury contamination in oceanic fishes is currently widespread, and of sufficient concern that the U.S. Food and Drug Administration issued a consumer alert on March 9, 2001, advising that pregnant women, women of childbearing age, nursing mothers, and young children should avoid eating shark, swordfish, king mackerel, and tilefish. Many states in the United States have issued similar warnings about potentially hazardous levels of mercury or other bioaccumulated toxins in freshwater sport fish.

Arsenic, copper, lead, and cadmium are often deposited in lakes and streams from the air near emitting facilities. These substances may also enter waterways from runoff from slag piles, mine drainage, and industrial effluent. Effluents from electroplating contain a number of heavy metal constituents. Heavy metals, copper in particular, may be toxic to aquatic species as well as harmful to human health.

In the past quarter century, a considerable number of incidents of surface water contamination by hazardous and carcinogenic organic compounds were reported in the United States. The sources of these include effluent from petrochemical industries and agricultural runoff, which contains both pesticide and fertilizer residues. Trace quantities of chlorinated hydrocarbon compounds in drinking water may also be attributed to the chlorination of organic residues by chlorine added as a disinfectant. The production of these disinfection by-products is difficult to eliminate in the drinking water treatment process, but maintaining clean, unpolluted, source water is the first step.

## CONCLUSION

Water pollution stems from many sources and causes, only a few of which are discussed here. Rivers and streams demonstrate some capacity to recover from the