Environmental Management & Pollution

WATER QUALITY

5.1 Overview

This lesson introduced you to the water environment and the natural cycle that connects all waters on earth: the hydrologic cycle. It introduced you to the natural conditions that influence water quality and to some important concerns about different waters. You can more fully appreciate these natural conditions and concerns if you understand some of the basic chemical and biological properties of water.

What is clean water? Clean water is a clear creek cascading down a steep mountainside, and a refreshing glass of ice water on a hot day. It is a spring-fed brook filled with wild trout, and rain falling on a parched field. It is a lush, green wetland teeming with vegetation and wildlife, and a dynamic estuary surging with the tide, filled with healthy shellfish and salmon. Clean water is all of these and more.

5.2 The Quality of Earth Water

The quality of the earth's water is vital to our existence. We need ample clean water to quench our thirst, irrigate our fields, and sustain all life forms in the environment. We must have clean water in our homes, communities, businesses, industries, and in nature. We need clean water today and we will need it tomorrow. We rely on clean water in almost every aspect of our lives. We rely on it for drinking, bathing, cooking, swimming, fishing, and boating. We count on it for growing and processing our food and nourishing the plants and animals. We count on the aesthetic qualities of clean water to nourish our souls.

Unfortunately, we have no guarantee that clean water, relied on so heavily, will always be available. The supply of clean water on the earth is finite, and it is being threatened by water pollution. ***Water pollution is a serious problem today, in spite of our efforts to control it.*** The Environmental Protection Agency (EPA) estimates that approximately one third of all the waters in the United States are unsafe for swimming, fishing, and drinking.

Many of these waters are suffering the effects of indirect or diffuse discharges of pollutants associated with *stormwater runoff from adjacent lands*. We call this type

of water pollution ***nonpoint source pollution*** to differentiate it from ***direct*** or ***point source discharges*** of pollutants into waterways from pipes and outfalls. The polluted waters in the United States include our major waterways and their tributaries.

The Mississippi River, for instance, which drains about half of the continental United States, has serious water pollution problems. Water quality degradation caused by erosion and sedimentation, municipal and industrial discharges, and agricultural runoff threaten its fish and wildlife. Structures constructed on the Mississippi for navigation and flood control also contribute to the decline in water quality.

The Columbia River, which drains most of the northwestern United States and parts of British Columbia, also has water pollution problems. Municipal and industrial discharges and agricultural runoff deliver a wide variety of pollutants to the river.

Some of these pollutants, like dioxins and pesticides, are toxic in extremely small concentrations. Dams constructed on the Columbia River for hydropower and irrigation have altered water quality and fish habitat, contributing to the near extinction of some populations of salmon. The spring Chinook salmon run on the Columbia, which once numbered one hundred thousand fish or more, dwindled to an estimated ten to fifteen thousand in 1995, a decrease of almost ninety percent. The Snake River sockeye salmon, which migrate up the Columbia River, have fared even worse.

In 1994, only one wild sockeye salmon returned to its spawning ground in Redfish Lake, Idaho. Tributaries of these major waterways, such as Oregon's Tualatin River—a tributary of the Columbia—also are threatened by water pollution. The Tualatin River has high nutrient concentrations due to municipal and industrial discharges, stormwater runoff, and natural soil conditions. These high concentrations of nutrients, combined with warm water temperatures, cause unsightly algal blooms and unhealthy, fluctuating oxygen levels.

Even greater problems exist in other parts of the world, where water quality has been a lower priority until recently. ***Parts of the Baltic Sea in Eastern Europe, for example, contain almost no fish or other aquatic life because of water pollution.*** Industries and municipalities in Germany, Poland, Denmark, and other surrounding countries have discharged untreated or partially treated wastes and wastewaters into the Baltic Sea for decades. Now, parts of the Baltic Sea's water and sediment

are severely contaminated and few organisms can survive. In southern Poland, the Vistula River and others like it are highly contaminated with pollutants from mining and other heavy industrial activities. In other parts of Poland, rivers are contaminated with pollutants from food processing plants, textile mills, and municipal wastes. Many municipalities and industries still discharge untreated wastes and wastewaters into Poland's rivers and streams.

But there is hope. Until a few years ago, twenty million gallons of untreated municipal and industrial wastewater were pouring into the Rio Grande near Nuevo Laredo, Mexico every day. These untreated discharges were contaminating the water, sediment, and fish downstream of Nuevo Laredo with toxic compounds. In 1996, the community finally constructed a wastewater treatment plant and began treating these waste streams to remove pollutants prior to discharge.

Clearly, we cannot take clean water for granted. It is crucial to our survival, prosperity, and happiness and it is being threatened in all parts of the world. Moreover, the water environment knows no political boundaries. Water and the pollutants in it move freely across borders. We must address the world's water pollution problems not only as individual states and nations, but also as members of a greater worldwide environmental community.

Most people are concerned about clean water, yet may feel uninformed. They may not know about the many sources of water pollution or the methods used to prevent and control it. They may not be aware of the rules and regulations adopted to protect our water. They could be intimidated by the science of water pollution control. Many of us know how important clean water is, but we may not know how to get involved to help protect it.

5.3 The Water Environment

Where does the water environment begin? It begins where a single drop of rain falls to earth. This raindrop joins with others like it to form tiny trickles. These trickles combine and run off the land to create rivulets, creeks, streams, and rivers. The small streams and mighty rivers of the world unite to produce the vast oceans and seas that surround us.

The water environment is the entire world of water that we know and love: from cool, clear mountain streams to the dynamic and salty oceans. It is the loud cascading creeks and waterfalls and the quiet, slow moving rivers and peaceful lakes. It is the wetland waters filled with lush, green vegetation and the sterile melt waters running from glaciers across barren landscapes. The water environment also

includes secret waters—springs, seeps, and groundwater—and the often-invisible atmospheric water poised to fall on the earth in a sudden cloudburst.

5.4 The Hydrologic Cycle

Although the world of water is enormous and all encompassing, it is connected in a single natural cycle. Water moves from the ocean to the land and back to the ocean again continuously. This cyclic movement of water through the environment is called the hydrologic cycle. It begins as water moves from the ocean's surface into the air above through evaporation. During evaporation, only the fresh water vapor and other volatile compounds enter the atmosphere. Minerals, salts, and other impurities are left behind in the ocean. The buildup of these minerals and salts over time has made the ocean salty.

Water evaporates into the atmosphere and forms clouds above the ocean. The prevailing ocean winds blow these clouds of moist air inland and as they rise to move over the mountaintops, the air in them cools. Because cold air cannot hold as much moisture as warm air, water falls from the clouds as rain or snow.

The moment a raindrop strikes the surface of the earth, it begins its journey back to the sea. Sometimes the raindrop soaks into the earth and moves slowly into the groundwater. Sometimes it runs off the land surface and moves quickly in a swift-flowing stream. Other times the raindrop rests in deep river pools or lakes, is taken up by plants and animals, or enters the atmosphere again through evaporation. Ultimately, the raindrop makes its way back to the ocean, which is like a giant reservoir. Water is stored in the ocean until it is delivered to the land as a result of evaporation and precipitation. Once the water reaches the land, it begins making its way back to the ocean through groundwater or surface water flow, and the cycle continues.

All the waters of the world are connected by the hydrologic cycle. The rivers and streams are connected to the lakes, ponds, and wetlands. The surface water is connected to the groundwater. The rivers are connected to the bays and estuaries, which are connected to the oceans and seas. These connections are extremely important to water quality; they allow materials entering the water at any point in the hydrologic cycle to move from one water body to the next. For instance, precipitation falling on exposed mine tailings high in the mountains may pick up and carry contaminants from the tailings into nearby streams, downstream lakes, and groundwater. These contaminants may show up many miles from their point of origin, possibly polluting a community's drinking water supply.

Although water takes on many different forms as it moves continuously through the hydrologic cycle, the world's supply of water is finite; we cannot make any more of it. What we have now is all we get. Because it is finite, protecting its quality is crucial. Our very survival depends on it.

5.5 Natural Conditions That Influence Water Quality

The different forms water takes in nature—the rivers and streams, lakes and ponds, wetlands, bays and estuaries, oceans and seas, and groundwater—all have unique water quality characteristics. These characteristics are influenced by the activities of humans and also by natural conditions in the environment. Some of the more important natural conditions include geology, climate, the amount and type of vegetation present, morphological characteristics such as the size, shape, depth, and width of water bodies, and the location of the water on the earth's landscape.

Geology - The geology of an area determines, in large part, the mineral makeup of its waters. For instance, water in areas with limestone deposits contains limestone minerals such as calcium and magnesium. These minerals dissolve and enter the water when it passes over rock formations and soil containing limestone. Water also will pick up small concentrations of metals such as copper, lead, and zinc when it passes over rocks and soils containing these elements. Because all minerals dissolve to some extent in water, you can discover much about the mineral content in water in any given area by learning what kind of minerals are found in the area's soil and rock.

Climate - Climate influences water quality because temperature, precipitation, and wind affect the physical, chemical, and biological characteristics of water. Temperature is one of the most important natural conditions influencing water quality. It affects the amount of dissolved gases, such as oxygen, in the water. Warm water contains less oxygen than cold water, making it difficult for some organisms to survive.

Also, chemical and biological reactions occur more rapidly in warm than in cold water, resulting in stress on some aquatic organisms. The amount of precipitation falling in an area determines the number and size of its water bodies. Fewer water bodies exist in dry climates, and those that do tend to be smaller and more susceptible to pollution. Small bodies of water are more likely to become polluted than large bodies because they have less water available for diluting the effects of pollutants. In other words, an equal amount of pollutant would cause considerably more damage if discharged into a small creek than if discharged into a large river,

simply because of dilution. Wind is responsible for mixing the surface of waters, helping to enrich them with important gases like oxygen and carbon dioxide. Wind also influences the rate of evaporation from the surface of the water.

Vegetation - The presence or absence of vegetation also influences the natural quality of water. In areas where it is abundant, vegetation falls into the water, mixes with it, breaks apart, decomposes, and becomes part of the water. In some cases, excessive decaying vegetation can color the water. For example, one of the tributaries of the mighty Amazon River in South America is the color of ink because of decaying organic material. It is called the Rio Negro, or Black River, for obvious reasons.

The water in wetlands is often a rich, brown, tea-like color because of decaying vegetation. In areas where vegetation is not abundant—in high mountain areas above timberline, for example—water contains less natural organic material. Sometimes waters located above timberline will be crystal clear and almost sterile, containing few minerals and nutrients and few fish or other aquatic organisms. Vegetation such as trees and shrubs growing along stream corridors helps maintain desirable levels of dissolved gases in the water by shading it and keeping it cooler. Vegetation also acts as a filter to remove solid particles that are suspended in the water and helps to bind soil particles together to prevent erosion.

Morphology - The shape and dimensions of water bodies have a direct influence on their quality. For example, a shallow lake will generally be mixed thoroughly by the action of waves and wind. This mixing action helps to distribute minerals and dissolved gases equally throughout the lake. In contrast, a deep lake generally will not be well mixed. The bottom of the lake may have less oxygen and more minerals than the surface of the lake. Deep, unmixed lakes can develop layers, each with different water quality characteristics. (Stratification is the term used to describe this layering effect.)

Because streams on steep slopes flow swiftly, they often have better water quality than streams on gentler slopes. Streams on steep slopes experience more turbulence as water cascades over rocks and logs, adding oxygen to the water by mixing with the air. Streams located on mild slopes do not have the benefit of turbulent mixing to aerate the water. Swift-flowing streams, however, also have greater energy for causing erosion. Sediment from eroded stream banks may become suspended in the water, increasing turbidity and lowering the quality of the water.

Location - The location of a water body on the earth's landscape determines the natural conditions described above—geology, climate, vegetation, and morphology—and thus the natural quality of its water. As in real estate, location means everything. For instance, a slow-moving river meandering through a broad, flat valley will not have the same quality as a high mountain stream. The high mountain stream will likely be clear and cool while the valley river may be turbid and warm simply because of location and natural conditions. We can see now that, even without humans, each of our water bodies would have different characteristics because of natural conditions in the environment. Unfortunately, the activities of humans tend to compound these natural differences, giving rise to many of the concerns we have about water quality.

5.6 Human Activities That Affect Water Quality

Many human activities threaten water quality. Some of these activities have been occurring for many generations and some began more recently. This section reviews these activities in relationship to the different water forms in the environment.

- ***Rivers and streams*** are the highways of the water world. People have used them to transport themselves and their goods from the mountaintops to the seas for centuries. Unfortunately, humans have used them also to dispose of and transport their wastes, a practice that seriously threatens water quality in our rivers and streams.

Since ancient times, villages have been built on riverbanks. Wastes from these villages were thrown into the rivers to be carried away. At first, few people lived downstream and the rivers had the natural capacity to assimilate the waste and cleanse themselves. This natural capacity for a water body to cleanse itself is called assimilative capacity. As the population continued to grow, however, the assimilative capacities of the waters were overburdened and the rivers could no longer cleanse themselves.

Today, most of us know it is unacceptable to discharge untreated waste into a river or stream. Waste dumped into a river upstream will be carried downstream to the users below. The phrase "we all live downstream" is often used to remind us to use our rivers wisely, respecting the rights of all downstream users. In turn, we hope the people living upstream from us will respect our rights.

Although wastewater from most communities and industries is now routinely treated to remove pollutants, ultimately it is discharged into our rivers along with

any pollutants that remain after treatment. Our efforts to keep rivers clean and healthy compete with this age-old practice of using our rivers to transport wastes. Sometimes wastes enter our rivers and streams through more spread out, indirect, or diffuse discharges, or nonpoint source discharges. For instance, fertilizers, pesticides, and herbicides can be carried from our lawns and fields into nearby waters during and after rainstorms, as a result of stormwater runoff.

- ***Lakes and Ponds*** - Our ancestors also established settlements on the banks of lakes and often discharged their wastes directly into them. Today, most of us realize that disposing of waste directly into a lake is a poor practice because it causes water pollution. Unfortunately, this practice continues in some areas and only recently has been discontinued in others. As an example, raw sewage was poured into Dal Lake high in the Himalayan Mountains during a recent civil war. The military turned resort hotels located along the shoreline into encampments and discharged untreated sewage directly into the lake, causing it to become highly polluted.

In Oregon, one of the more progressive environmental states in the United States, two municipalities were required to stop discharging their treated wastewater into downstream lakes only recently. Pollutants remaining in the wastewater, even after treatment, were harming the lakes. State environmental officials worked with community leaders to educate them about water pollution problems caused by these discharges. They also helped the communities find other means of disposal.

Direct discharges into lakes and ponds also occur from stormwater runoff. Since stormwater picks up pollutants as it runs across the surface of the land, all activities occurring on the land surrounding a lake have the potential to contribute pollutants. For instance, many people remain interested in having a home or summer cabin at the edge of a lake. Unfortunately, residential development often results in both direct and indirect discharges of wastes and wastewater into our lakes. Direct discharges of fertilizers, pesticides, nutrients, and sediment may result from stormwater running off properties surrounding the lake. These direct discharges may also include materials from improper car and home maintenance such as gas, oil, antifreeze, soaps, and paints.

Indirect discharges may occur when homes are built around a lake where no community sewer system is in place. People often use septic systems in these areas. Unfortunately, sewage from the septic tanks and their drain fields may seep into the groundwater and move with the groundwater into the lake, causing

contamination. This pattern of polluting lakes by improper use of septic systems has occurred across the United States and abroad.

- ***Wetlands*** are truly rich. They are rich in nutrients, animal life, and vegetation. They support an abundant and diverse population of plants and animals, providing habitat for many species of aquatic vegetation and serving as a spawning ground and nursery for many species of fish. In fact, approximately one third of the plant and animal species listed as threatened and endangered in the United States depend on wetlands for habitat.

Wetlands connect the upland world with the world of open water, while providing a protective buffer or transition zone between the two. They protect the uplands from erosion by absorbing the effect of waves on the shoreline of open water. They also protect open water from upland disturbances. Wetlands are also nature's filters. They filter out pollutants as water moves from upland into open water bodies. Wetlands provide flood control and groundwater recharge zones. Fresh water wetland, Tillamook County, Oregon which are areas where surface water enters the groundwater and replenishes it.

If wetlands are so important, why is their existence in jeopardy? Until recently, society believed they were undesirable and unimportant. We have misunderstood them and considered them to be useless, unwanted swamps. Part of this misunderstanding comes from folklore, literature, and the popular media. Often, wetlands are portrayed as vile places were evil and mysterious events occur. For example, in *Oliver Twist*, Dickens associates evil deeds and unsavory characters with an area he describes as a low, unwholesome swamp bordering the river. Motion pictures like the Bogart and Hepburn classic ***The African Queen*** depict wetlands as undesirable places infested with mosquitoes and other pests.

These popular misconceptions have resulted in a threat to our wetlands even more serious than the threat to the quality of our rivers or lakes. Their very existence is in jeopardy. Wetlands continue to be lost throughout the world at an alarming rate. In the United States, for example, over ninety million acres of wetlands have been lost to date.

Scientists estimate that only a little more than half of the wetlands that existed when European settlers moved to American are still in existence. In the past, many of our wetlands were lost because people drained them and turned them into agricultural properties. Today, the biggest threat is land development. As land values continue to increase and developable land and agricultural land becomes

more scarce and expensive, the pressure to eliminate wetlands increases. We have only recently recognized how important wetlands are to the environment and enacted federal and state laws and local ordinances to protect them.

- ***Bays and Estuaries*** link the fresh water in our rivers and streams to the salt water in the ocean. These highly productive parts of the environment contain hundreds of species of plants and animals. They are dynamic, and fluctuate according to the movement of the tides and the changes in the fresh and salt water entering them.

On an incoming tide, saltwater enters the bay from the ocean and mixes with fresh water from upstream tributaries. The movement of saltwater and fresh water in and out of the bay in response to the tide and the inflows from tributaries creates brackish water—a mixture of salt and fresh water. Because of the constantly changing effects of the tide and tributaries, the characteristics of the water in a bay vary considerably with time and location.

The water quality in our bays and estuaries is threatened by upstream activities, since wastes discharged into our rivers and streams are carried into the bays and estuaries below. The waste materials may stay suspended while in the river because of the rapid movement and energy of the water, but when the river slows down as it reaches the estuary, the waste materials settle out. Some of the activities that take place in our bays and estuaries also threaten their quality. For instance, the practice of storing and distributing petroleum products out of our bays and estuaries for transportation efficiency can result in contamination of both open water and shoreline if they are spilled or leaked. Also, boat maintenance activities such as stripping, sanding, and painting can harm water quality and aquatic organisms.

For instance, shellfish growing in waters contaminated with tributilin (TBT), an additive used in boat paint to keep barnacles from growing on the hull, become deformed. Many of the studies conducted on water pollution in bays and estuaries have focused on shellfish because of public health concerns and because of the economic importance of shellfish to coastal communities. Bacteria from animal and human wastes that enter the water have contaminated shellfish and have become a recurring problem in some areas. To protect the health of the organisms living in our bays and estuaries, as well as our own health, we must become aware of and begin controlling the activities that pollute them.

- ***Oceans and Seas*** Like bays and estuaries, our oceans and seas are forever changing. Their characteristics change due to climatic conditions and to movements of the moon and earth. Unfortunately, their characteristics have also changed for the worse because of human activities.

People have always discharged their wastes into the seas and they continue to do so. Because of their vast size, society has incorrectly assumed that oceans have an infinite capacity to assimilate waste materials. In recent years we have learned more about the finite nature of the oceans and the localized effects of pollution. For instance, medical wastes discharged into the Atlantic Ocean, including used needles and syringes, have washed up on beaches in the eastern United States. As previously mentioned, almost no fish or other aquatic life forms exist in parts of the Baltic Sea because industrial and municipal wastes have polluted the aquatic habitat.

Perhaps the biggest threat to the quality of water in our oceans and seas comes from oil spills. The 1989 Exxon Valdez disaster in the Gulf of Alaska is one extreme example of this. The Gulf of Mexico has also been severely damaged by oil pollution. Water and sediment in the Gulf of Mexico and tributaries such as Mexico's Coatzacoalcos River are highly contaminated with petroleum products. This area, which supports the largest petroleum refinery complex in Latin America, has been the site of a number of disastrous oil spills. Petroleum spills in the Persian Gulf, the North Sea, and other parts of the world are also degrading water quality in our oceans and seas.

Indirect discharges also threaten water quality in the oceans. Because of the hydrologic cycle, all materials entering upstream waters that are not removed naturally or through treatment are discharged into the oceans. The oceans and seas are the ultimate sinks for all of the water on the planet and all of the pollutants dissolved or suspended in the water. The oceans and seas are not infinite. They are particularly susceptible to the localized effects of pollution. We threaten their quality every time we discharge pollutants into them directly or indirectly.

- ***Groundwater*** is water is water stored in the soil and rock formations below the earth's surface. It is the primary source of drinking water for many communities and the secondary source for others. Groundwater is used extensively for irrigation. It is also an important source of water for rivers and streams, especially during extended dry periods. Groundwater emerging at the bases of mountains and foothills provides the base flow of streams in the area during the dry season.

Groundwater provides the single largest supply of fresh water on the planet. It is used more extensively now than ever before because of society's increasing demand for fresh water. It is also being used more frequently today because drought conditions and contamination of surface water have reduced the availability of clean, fresh water at the surface.

As you learned earlier in this chapter, groundwater is connected to all other water forms in the environment through the hydrologic cycle. These connections make the threat of contamination to the surface water a threat to groundwater quality as well. Activities taking place at the earth's surface are primarily responsible for groundwater pollution. For example, groundwater pollution can occur due to accidental spills and improper disposal of petroleum products and industrial solvents; over-application of fertilizers, pesticides, food wastes, and animal wastes to the land; and the use of septic systems in unsuitable locations.

Because groundwater is usually remote and inaccessible, it is difficult or impossible to clean once it becomes polluted. Methods of cleaning groundwater, such as isolating the contaminated area and pumping and treating the contaminated water, are not always successful. Regardless of success, attempts to clean groundwater are always expensive.

- ***Atmospheric Water*** *a*s part of the hydrologic cycle, water evaporating from the ocean enters the atmosphere and then falls onto the land or back into the ocean as precipitation. This atmospheric water is the initial source of all fresh water in the environment.

Recall that when water evaporates off the ocean's surface, salts, minerals, and other impurities that do not evaporate are left Bear Lake, Idaho behind. Thus, atmospheric water enters the hydrologic cycle in a relatively pure form. Unfortunately, the quality of the water in our atmosphere is threatened by air pollution. Air contaminated with sulfur and nitrogen compounds, for instance, mixes with water in the atmosphere and produces acids. When this contaminated atmospheric water falls as precipitation, it turns into acid rain, damaging and degrading the soil, vegetation, and water below.

Acid rain has been responsible for widespread environmental damage throughout the world, from the Appalachian and Adirondack Mountains of the eastern United States to the mountains of Eastern Europe and Scandinavia. Acid rain is particularly damaging to the aquatic environment. It has caused thousands of lakes

and other water bodies throughout the world to become too acidic to support fish or other aquatic organisms.

Air polluted with carbon compounds contributes to another water quality concern: the greenhouse effect. The greenhouse effect, which is caused by atmospheric pollution insulating the earth and making it retain heat like a greenhouse, is thought to be warming the entire planet, including the polar ice caps and all the earth's waters. This condition is an important water quality concern because changes in the earth's temperature have a profound effect on all parts of the water environment. The temperature of the earth not only controls the melting and freezing of water, it controls the rates of chemical and biological reactions and the concentration of gases in the earth's water.