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What Is Water Pollution?

Water pollution occurs when harmful substances—often chemicals or microorganisms—contaminate a stream, river, lake, ocean, aquifer, or other body of water, degrading water quality and rendering it toxic to humans or the environment.

What Are the Causes of Water Pollution?

Water is uniquely vulnerable to pollution. Known as a "universal solvent," water is able to dissolve more substances than any other liquid on earth. Toxic substances from farms, towns, and factories readily dissolve into and mix with it, causing water pollution.

Categories of Water Pollution

Groundwater

When rain falls and seeps deep into the earth, filling the cracks, crevices, and porous spaces of an aquifer (basically an underground storehouse of water), it becomes groundwater—one of our least visible but most important natural resources. Nearly 40 percent of Americans rely on groundwater, pumped to the earth's surface, for drinking water. For some folks in rural areas, it's their only freshwater source. Groundwater gets polluted when contaminants—from pesticides and fertilizers to waste leached from landfills and septic systems—make their way into an aquifer, rendering it unsafe for human use. Ridding groundwater of contaminants can be difficult to impossible, as well as costly. Once polluted, an aquifer may be unusable for decades, or even thousands of years. Groundwater can also spread contamination far from the original polluting source as it seeps into streams, lakes, and oceans.

Surface water

Covering about 70 percent of the earth, surface water is what fills our oceans, lakes, rivers, and all those other blue bits on the world map. Surface water from freshwater sources (that is, from sources other than the ocean) accounts for more than 60 percent of the water delivered to American homes. But a significant pool of that water is in peril. According to the most recent surveys on national water quality from the U.S. Environmental Protection Agency, nearly half of our rivers and streams and more than one-third of our lakes are polluted and unfit for swimming, fishing, and drinking. Nutrient pollution, which includes nitrates and phosphates, is the leading type of contamination in these freshwater sources. While plants and animals need these nutrients to grow, they have become a major pollutant due to farm waste and fertilizer runoff. Municipal and industrial waste discharges contribute their fair share of toxins as well. There's also all the random junk that industry and individuals dump directly into waterways.

Ocean water

Eighty percent of ocean pollution (also called marine pollution) originates on land—whether along the coast or far inland. Contaminants such as chemicals, nutrients, and heavy metals are carried from farms, factories, and cities by streams and rivers into our bays and estuaries; from there they travel out to sea. Meanwhile, marine debris—particularly plastic—is blown in by the wind or washed in via storm drains and sewers. Our seas are also sometimes spoiled by oil spills and leaks—big and small—and are consistently soaking up carbon pollution from the air. The ocean absorbs as much as a quarter of man-made carbon emissions.

Point source

When contamination originates from a single source, it's called point source pollution. Examples include wastewater (also called effluent) discharged legally or illegally by a manufacturer, oil refinery, or wastewater treatment facility, as well as contamination from leaking septic systems, chemical and oil spills, and illegal dumping. The EPA regulates point source pollution by establishing limits on what can be discharged by a facility directly into a body of water. While point source pollution originates from a specific place, it can affect miles of waterways and ocean.

Nonpoint source

Nonpoint source pollution is contamination derived from diffuse sources. These may include agricultural or stormwater runoff or debris blown into waterways from land. **Nonpoint source pollution is** the leading cause of water pollution in U.S. waters, but it's difficult to regulate, since there's no single, identifiable culprit.

Transboundary

It goes without saying that water pollution can't be contained by a line on a map. Transboundary pollution is the result of contaminated water from one country spilling into the waters of another. Contamination can result from a disaster—like an oil spill—or the slow, downriver creep of industrial, agricultural, or municipal discharge.

The Most Common Types of Water Contamination

Agricultural

Not only is the agricultural sector the biggest consumer of global freshwater resources, with farming and livestock production using about 70 percent of the earth's surface water supplies, but it's also a serious water polluter. Around the world, agriculture is the leading cause of water degradation. In the United States, agricultural pollution is the top source of contamination in rivers and streams, the second-biggest source in wetlands, and the third main source in lakes. It's also a major contributor of contamination to estuaries and groundwater. Every time it rains, fertilizers, pesticides, and animal waste from farms and livestock operations wash nutrients and pathogens—such bacteria and viruses—into our waterways. Nutrient pollution, caused by excess nitrogen and phosphorus in water or air, is the number-one threat to water quality worldwide and can cause algal blooms, a toxic soup of blue-green algae that can be harmful to people and wildlife.

Sewage and wastewater

Used water is wastewater. It comes from our sinks, showers, and toilets (think sewage) and from commercial, industrial, and agricultural activities (think metals, solvents, and toxic sludge). The term also includes stormwater runoff, which occurs when rainfall carries road salts, oil, grease, chemicals, and debris from impermeable surfaces into our waterways

More than 80 percent of the world's wastewater flows back into the environment without being treated or reused, according to the United Nations; in some least-developed countries, the figure tops 95 percent. In the United States, wastewater treatment facilities process about 34 billion gallons of wastewater per day. These facilities reduce the amount of pollutants such as pathogens, phosphorus, and nitrogen in sewage, as well as heavy metals and toxic chemicals in industrial waste, before discharging the treated waters back into waterways. That's when all goes well. But according to EPA estimates, our nation's aging and easily overwhelmed sewage treatment systems also release more than 850 billion gallons of untreated wastewater each year.

Oil pollution

Big spills may dominate headlines, but consumers account for the vast majority of oil pollution in our seas, including oil and gasoline that drips from millions of cars and trucks every day. Moreover, nearly half of the estimated 1 million tons of oil that makes its way into marine environments each year comes not from tanker spills but from land-based sources such as factories, farms, and cities. At sea, tanker spills account for about 10 percent of the oil in waters around the world, while regular operations of the shipping industry—through both legal and illegal discharges—contribute about one-third. Oil is also naturally released from under the ocean floor through fractures known as seeps.

Radioactive substances

Radioactive waste is any pollution that emits radiation beyond what is naturally released by the environment. It's generated by uranium mining, nuclear power plants, and the production and testing of military weapons, as well as by universities and hospitals that use radioactive materials for research and medicine. Radioactive waste can persist in the environment for thousands of years, making disposal a major challenge. Consider the decommissioned Hanford nuclear weapons production site in Washington, where the cleanup of 56 million gallons of radioactive waste is expected to cost more than $100 billion and last through 2060. Accidentally released or improperly disposed of contaminants threaten groundwater, surface water, and marine resources.

What Are the Effects of Water Pollution?

On human health

To put it bluntly: Water pollution kills. In fact, it caused 1.8 million deaths in 2015, according to a study published in *The Lancet*. Contaminated water can also make you ill. Every year, unsafe water sickens about 1 billion people. And low-income communities are disproportionately at risk because their homes are often closest to the most polluting industries.

Waterborne pathogens, in the form of disease-causing bacteria and viruses from human and animal waste, are a major cause of illness from contaminated drinking water. Diseases spread by unsafe water include cholera, giardia, and typhoid. Even in wealthy nations, accidental or illegal releases from sewage treatment facilities, as well as runoff from farms and urban areas, contribute harmful pathogens to waterways. Thousands of people across the United States are sickened every year by Legionnaires’ disease (a severe form of pneumonia contracted from water sources like cooling towers and piped water), with cases cropping up from California’s Disneyland to Manhattan’s Upper East Side.

Meanwhile, the plight of residents in Flint, Michigan—where cost-cutting measures and aging water infrastructure created the recent lead contamination crisis—offers a stark look at how dangerous chemical and other industrial pollutants in our water can be. The problem goes far beyond Flint and involves much more than lead, as a wide range of chemical pollutants—from heavy metals such as arsenic and mercury to pesticides and nitrate fertilizers—are getting into our water supplies. Once they're ingested, these toxins can cause a host of health issues, from cancer to hormone disruption to altered brain function. Children and pregnant women are particularly at risk.

Even swimming can pose a risk. Every year, 3.5 million Americans contract health issues such as skin rashes, pinkeye, respiratory infections, and hepatitis from sewage-laden coastal waters, according to EPA estimates.

On the environment

In order to thrive, healthy ecosystems rely on a complex web of animals, plants, bacteria, and fungi—all of which interact, directly or indirectly, with each other. Harm to any of these organisms can create a chain effect, imperiling entire aquatic environments.

When water pollution causes an algal bloom in a lake or marine environment, the proliferation of newly introduced nutrients stimulates plant and algae growth, which in turn reduces oxygen levels in the water. This dearth of oxygen, known as eutrophication, suffocates plants and animals and can create "dead zones," where waters are essentially devoid of life. In certain cases, these harmful algal blooms can also produce neurotoxins that affect wildlife, from whales to sea turtles.

Chemicals and heavy metals from industrial and municipal wastewater contaminate waterways as well. These contaminants are toxic to aquatic life—most often reducing an organism's life span and ability to reproduce—and make their way up the food chain as predator eats prey. That's how tuna and other big fish accumulate high quantities of toxins, such as mercury.

Marine ecosystems are also threatened by marine debris, which can strangle, suffocate, and starve animals. Much of this solid debris, such as plastic bags and soda cans, gets swept into sewers and storm drains and eventually out to sea, turning our oceans into trash soup and sometimes consolidating to form floating garbage patches. Discarded fishing gear and other types of debris are **responsible for harming more than 200 different species of marine life.**

Meanwhile, ocean acidification is making it tougher for shellfish and coral to survive. Though they absorb about a quarter of the carbon pollution created each year by burning fossil fuels, oceans are becoming more acidic. This process makes it harder for shellfish and other species to build shells and may impact the nervous systems of sharks, clownfish, and other marine life.

Role of microorganisms in Sewage Treatment

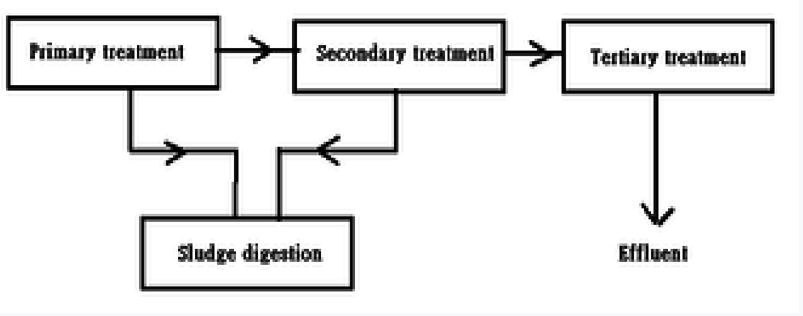

Figure1: general scheme of sewage treatment which shows the flow from primary treatment to tertiary treatment, and solid sludge digestion is also shown.

Sewage treatment is a process in which the pollutants are removed. The ultimate goal of sewage treatment is to produce an effluent that will not impact the environment. In the absence of sewage treatment, the results can be devastating as sewage can disrupt the environment.

The general processes of sewage treatment are primary, secondary and tertiary treatment. Primary treatment involves physical separation of sewage into solids and liquid by using a settling basin. The liquid sewage is then transferred to secondary treatment which focuses on removing the dissolved biological compound by the use of micro-organisms. The micro-organisms usually use aerobic metabolism to degrade the biological matter in the liquid sludge. Then tertiary treatment is required to disinfect the sewage so that it can be released into the environment. The solid sewage separated from primary treatment is transferred to a tank for sludge digestion which involves anaerobic degradation using micro-organisms.

Physical environment

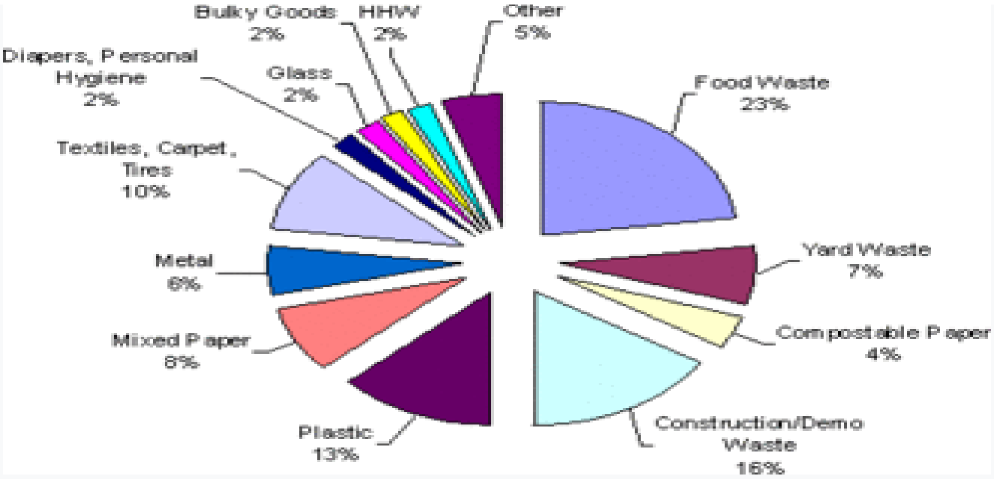

Figure 2: sewage composition in a urbanized city

The environment of the sewage treatment plant has to be controlled precisely because bacteria are sensitive to the oxygen level, pH level, temperature, and level of nutrient. In order for efficient degradation of biological matter to occur, these factors are controlled manually.

Sewage composition

Sewage is composed of organic matter such as carbohydrates, fats, oil, grease and proteins mainly from domestic waste. It also contains dissolved inorganic matter such as nitrogen species and phosphorous species mainly from agricultural use . It is essential to remove the nutrients before they are released to the environment because it interferes natural habitats by altering the chemical composition such as pH or oxygen level both directly and indirectly.

Oxygen level

Oxygen level is an important factor to secondary and tertiary treatment processes. Secondary treatment, oxygen is required as a terminal electron acceptor in organic matter degradation. For example, nitrification by *Nitrosomonas* and *Nitrobacter* species requires dissolved oxygen to occur. Oxygen in secondary treatment is provided manually by pumping oxygen into the sewage continuously which occurs in an aeration tank . In tertiary treatment, the removal of excess organic matter is enhanced by settling the sewage in a lagoon. This process is also aerobic, but it depends on the diffusion of oxygen because most organic matter has been degraded by secondary treatment .

pH

Acidity plays a crucial role in the breakdown of organic matter because pH affects the solubility of compounds which indirectly affect the accessibility by bacteria [8]. Also, bacteria responsible for organic matter degradation are sensitive to the pH of the environment. Extremely high or low pH levels are able to kill bacteria, deposition of organic matter occurs due to lack of degradation. Hence, the pH of sewage treatment is controlled to be around 7. A nitrifier in secondary treatment, *Nitrosomnas* requires a pH between 6~9 in order to be viable.

Temperature

The effect of temperature is influential for secondary treatment, but it is not important in primary treatment. Bacterial growth is sensitive to temperature because high temperature can increase the fluidity of the phospholipid bilayer which leads to cell lysis. However, bacteria are known to have higher enzymatic activity at higher temperature because of increased thermal energy. For example, when thermophilic sludge treatment is compared to mesophilic treatment, the sludge biodegradability is higher with thermophilic degradation. Hence the temperature has to be controlled precisely to maximize the efficiency of degradation but also allow the cell to remain viable.

Nutrients availability

There are a lot of nutrients available in the sewage because of human waste and agricultural runoff [3]. Bacteria can harvest the electron from organic matter and transfer it to a terminal electron acceptor which results in the break down of organic matter and energy conservation.

Microorganisms

Microorganiasmscan also be categorized by its metabolism.

Microorganisms with aerobic microbial process

Members of the *Nitrosomonas* genus is a gram negative bacterium responsible for the first stage of nitrification in sewage. They oxidize ammonium into nitrite. This bacterium prefers a pH around 6-9 and nitrify optimally at 20-30°C.

Members of the *Nitrobacter* genus is a gram negative bacterium responsible for the second stage of nitrification in the sewage. It oxidizes nitrite to nitrate using oxygen as a terminal electron acceptor. The bacteria has an optimum pH of 6~8, and an optimum temperature of 0~40°C.

Microorganism with anaerobic microbial process

Members of *Pseudomonas* genus is a gram negative denitrifying bacteria that use the chemical energy in organic matter to reduce nitrate into dinitrogen gas. Also, members of the *bacteroidetes* phylum are the gram negative bacteria responsible for the anaerobic fermentation of the solid sludge.

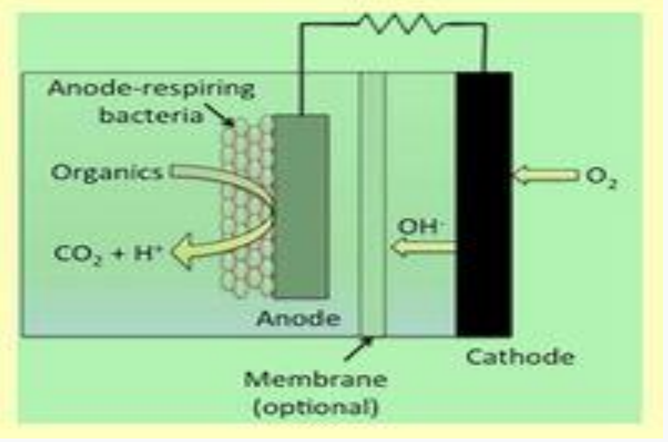

Figure 3: A general scheme of the function of microbial fuel cell

A research has shown the correlation between nutrient removal efficiency, light wavelength and light intensity. Xu et al. discovered that red and high intensity light maximizes the nutrient removal efficiency. Also, the use of pre-treated sludge is found to generate electricity in a microbial fuel cell. This can potentially lead to production of renewable energy