

# Water Pollution and Environment

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**ABSTRACT:** Water pollution (or aquatic pollution) is the contamination of water bodies, usually as a result of human activities, so that it negatively affects its uses.<sup>[1]:6</sup> Water bodies include lakes, rivers, oceans, aquifers, reservoirs and groundwater. Water pollution results when contaminants mix with these water bodies. Contaminants can come from one of four main sources: sewage discharges, industrial activities, agricultural activities, and urban runoff including stormwater.<sup>[2]</sup> Water pollution is either surface water pollution or groundwater pollution. This form of pollution can lead to many problems, such as the degradation of aquatic ecosystems or spreading water-borne diseases when people use polluted water for drinking or irrigation.<sup>[3]</sup> Another problem is that water pollution reduces the ecosystem services (such as providing drinking water) that the water resource would otherwise provide.

**KEYWORDS:** water pollution, contaminants, environment, groundwater, diseases, ecosystem, drinking, resource, sewage

## I. INTRODUCTION

Sources of water pollution are either point sources or non-point sources. Point sources have one identifiable cause, such as a storm drain, a wastewater treatment plant or an oil spill. Non-point sources are more diffuse, such as agricultural runoff.<sup>[4]</sup> Pollution is the result of the cumulative effect over time. Pollution may take the form of toxic substances (e.g., oil, metals, plastics, pesticides, persistent organic pollutants, industrial waste products), stressful conditions (e.g., changes of pH, hypoxia or anoxia, increased temperatures, excessive turbidity, changes of salinity), or the introduction of pathogenic organisms. Contaminants may include organic and inorganic substances. A common cause of thermal pollution is the use of water as a coolant by power plants and industrial manufacturers.

Control of water pollution requires appropriate infrastructure and management plans as well as legislation. Technology solutions can include improving sanitation, sewage treatment, industrial wastewater treatment, agricultural wastewater treatment, erosion control, sediment control and control of urban runoff (including stormwater management). A practical definition of water pollution is: "Water pollution is the addition of substances or energy forms that directly or indirectly alter the nature of the water body in such a manner that negatively affects its legitimate uses".<sup>[1]:6</sup> Water is typically referred to as polluted when it is impaired by anthropogenic contaminants. Due to these contaminants, it either no longer supports a certain human use, such as drinking water, or undergoes a marked shift in its ability to support its biotic communities, such as fish. The following compounds can all reach water bodies via raw sewage or even treated sewage discharges:

- Various chemical compounds found in personal hygiene and cosmetic products.
- Disinfection by-products found in chemically disinfected drinking water (whilst these chemicals can be a pollutant in the water distribution network, they are fairly volatile and therefore not usually found in environmental waters).<sup>[5]</sup>
- Hormones (from animal husbandry and residue from human hormonal contraception methods) and synthetic materials such as phthalates that mimic hormones in their action. These can have adverse impacts even at very low concentrations on the natural biota and potentially on humans if the water is treated and utilized for drinking water.<sup>[6][7][8]</sup>
- insecticides and herbicides, often from agricultural runoff.

If the water pollution stems from sewage (municipal wastewater), the main pollutants are: suspended solids, biodegradable organic matter, nutrients and pathogenic (disease-causing) organisms.<sup>[1]:6</sup>

The major groups of pathogenic organisms are: (a) bacteria, (b) viruses, (c) protozoans and (d) helminths.<sup>[1]:47</sup> In practice, indicator organisms are used to investigate pathogenic pollution of water because the detection of pathogenic organisms in water sample is difficult and costly, because of their low concentrations. The indicators (bacterial indicator) of fecal contamination of water samples most commonly used are: total coliforms (TC), fecal coliforms (FC) or thermotolerant coliforms, *E. coli*.<sup>[1]:47</sup>

Pathogens can produce waterborne diseases in either human or animal hosts.<sup>[10]</sup> Some microorganisms sometimes found in contaminated surface waters that have caused human health problems include: Burkholderia pseudomallei, Cryptosporidium parvum, Giardia lamblia, Salmonella, norovirus and other viruses, parasitic worms including the Schistosoma type.<sup>[11]</sup>

The source of high levels of pathogens in water bodies can be from human feces (due to open defecation), sewage, blackwater, or manure that has found its way into the water body. The cause for this can be lack of sanitation procedures or poorly functioning on-site sanitation systems (septic tanks, pit latrines), sewage treatment plants without disinfection steps, sanitary sewer overflows and combined sewer overflows (CSOs)<sup>[12]</sup> during storm events and intensive agriculture (poorly managed livestock operations).

The environmental effect of pharmaceuticals and personal care products (PPCPs) is being investigated since at least the 1990s. PPCPs include substances used by individuals for personal health or cosmetic reasons and the products used by agribusiness to boost growth or health of livestock. More than twenty million tons of PPCPs are produced every year.<sup>[21]</sup> The European Union has declared pharmaceutical residues with the potential of contamination of water and soil to be "priority substances".<sup>[3]</sup>

PPCPs have been detected in water bodies throughout the world. More research is needed to evaluate the risks of toxicity, persistence, and bioaccumulation, but the current state of research shows that personal care products impact the environment and other species, such as coral reefs<sup>[22][23][24]</sup> and fish.<sup>[25][26]</sup> PPCPs encompass environmental persistent pharmaceutical pollutants (EPPPs) and are one type of persistent organic pollutants. They are not removed in conventional sewage treatment plants but require a fourth treatment stage which not many plants have.<sup>[21]</sup>

In 2006, the most comprehensive study of pharmaceutical pollution of the world's rivers found that it threatens "environmental and/or human health in more than a quarter of the studied locations". It investigated 1,052 sampling sites along 258 rivers in 104 countries, representing the river pollution of 470 million people. It found that "the most contaminated sites were in low- to middle-income countries and were associated with areas with poor wastewater and waste management infrastructure and pharmaceutical manufacturing" and lists the most frequently detected and concentrated pharmaceuticals.<sup>[27][28]</sup>

- Environmental persistent pharmaceutical pollutants, which can include various pharmaceutical drugs and their metabolites (see also drug pollution), such as antidepressant drugs, antibiotics or the contraceptive pill.
- Metabolites of illicit drugs (see also wastewater epidemiology), for example methamphetamine and ecstasy.<sup>[29][30]</sup>

Solid waste can enter water bodies through untreated sewage, combined sewer overflows, urban runoff, people discarding garbage into the environment, wind carrying municipal solid waste from landfills and so forth. This results in macroscopic pollution— large visible items polluting the water— but also microplastics pollution that is not directly visible. The terms marine debris and marine plastic pollution are used in the context of pollution of oceans.

Microplastics persist in the environment at high levels, particularly in aquatic and marine ecosystems, where they cause water pollution.<sup>[31]</sup> 35% of all ocean microplastics come from textiles/clothing, primarily due to the erosion of polyester, acrylic, or nylon-based clothing, often during the washing process.<sup>[32]</sup>

Stormwater, untreated sewage and wind are the primary conduits for microplastics from land to sea. Synthetic fabrics, tyres, and city dust are the most common sources of microplastics. These three sources account for more than 80% of all microplastic contamination.<sup>[33][34]</sup>

Nutrient pollution, a form of water pollution, refers to contamination by excessive inputs of nutrients. It is a primary cause of eutrophication of surface waters (lakes, rivers and coastal waters), in which excess nutrients, usually nitrogen or phosphorus, stimulate algal growth.<sup>[42]</sup> Sources of nutrient pollution include surface runoff from farm fields and pastures, discharges from septic tanks and feedlots, and emissions from combustion. Raw sewage is a large contributor to cultural eutrophication since sewage is high in nutrients. Releasing raw sewage into a large water body is referred to as sewage dumping, and still occurs all over the world. Excess reactive nitrogen compounds in the environment are associated with many large-scale environmental concerns. These include eutrophication of surface waters, harmful algal blooms, hypoxia, acid rain, nitrogen saturation in forests, and climate change.<sup>[43]</sup>

Thermal pollution, sometimes called "thermal enrichment", is the degradation of water quality by any process that changes ambient water temperature. Thermal pollution is the rise or fall in the temperature of a natural body of water caused by human influence. Thermal pollution, unlike chemical pollution, results in a change in the physical properties of water. A common cause of thermal pollution is the use of water as a coolant by power plants and industrial

manufacturers.<sup>[44]</sup> Urban runoff—stormwater discharged to surface waters from rooftops, roads and parking lots—and reservoirs can also be a source of thermal pollution.<sup>[45]</sup> Thermal pollution can also be caused by the release of very cold water from the base of reservoirs into warmer rivers.

Elevated water temperatures decrease oxygen levels (due to lower levels of dissolved oxygen, as gases are less soluble in warmer liquids), which can kill fish (which may then rot) and alter food chain composition, reduce species biodiversity, and foster invasion by new thermophilic species

Groundwater pollution (also called groundwater contamination) occurs when pollutants are released to the ground and make their way into groundwater. This type of water pollution can also occur naturally due to the presence of a minor and unwanted constituent, contaminant, or impurity in the groundwater, in which case it is more likely referred to as contamination rather than pollution. Groundwater pollution can occur from on-site sanitation systems, landfill leachate, effluent from wastewater treatment plants, leaking sewers, petrol filling stations, hydraulic fracturing (fracking) or from over application of fertilizers in agriculture. Pollution (or contamination) can also occur from naturally occurring contaminants, such as arsenic or fluoride.<sup>[48]</sup> Using polluted groundwater causes hazards to public health through poisoning or the spread of disease (water-borne diseases).

In many areas of the world, groundwater pollution poses a hazard to the wellbeing of people and ecosystems. One-quarter of the world's population depends on groundwater for drinking, yet concentrated recharging is known to carry short-lived contaminants into carbonate aquifers and jeopardize the purity of those waters.<sup>[49]</sup>

## II. DISCUSSION

Industrial processes that use water also produce wastewater. This is called industrial wastewater. Using the US as an example, the main industrial consumers of water (using over 60% of the total consumption) are power plants, petroleum refineries, iron and steel mills, pulp and paper mills, and food processing industries.<sup>[2]</sup> Some industries discharge chemical wastes, including solvents and heavy metals (which are toxic) and other harmful pollutants.

Industrial wastewater could add the following pollutants to receiving water bodies if the wastewater is not treated and managed properly:

- Heavy metals, including mercury, lead, and chromium
- Organic matter and nutrients such as food waste: Certain industries (e.g. food processing, slaughterhouse waste, paper fibers, plant material, etc.) discharge high concentrations of BOD, ammonia nitrogen and oil and grease.<sup>[56]:180[13]</sup>
- Inorganic particles such as sand, grit, metal particles, rubber residues from tires, ceramics, etc.;
- Toxins such as pesticides, poisons, herbicides, etc.
- Pharmaceuticals, endocrine disrupting compounds, hormones, perfluorinated compounds, siloxanes, drugs of abuse and other hazardous substances<sup>[57][58][59]</sup>
- Microplastics such as polyethylene and polypropylene beads, polyester and polyamide<sup>[60]</sup>
- Thermal pollution from power stations and industrial manufacturers
- Radionuclides from uranium mining, processing nuclear fuel, operating nuclear reactors, or disposal of radioactive waste.
- Some industrial discharges include persistent organic pollutants such as per- and polyfluoroalkyl substances (PFAS).<sup>[15][16]</sup>

Agriculture is a major contributor to water pollution from nonpoint sources. The use of fertilizers as well as surface runoff from farm fields, pastures and feedlots leads to nutrient pollution.<sup>[62]</sup> In addition to plant-focused agriculture, fish-farming is also a source of pollution. Additionally, agricultural runoff often contains high levels of pesticides.<sup>[2]</sup>

Air deposition is a process whereby air pollutants from industrial or natural sources settle into water bodies. The deposition may lead to polluted water near the source, or at distances up to a few thousand miles away. The most frequently observed water pollutants resulting from industrial air deposition are sulfur compounds, nitrogen compounds, mercury compounds, other heavy metals, and some pesticides and industrial by-products. Natural sources of air deposition include forest fires and microbial activity.<sup>[63]</sup>

Acid rain is caused by emissions of sulfur dioxide and nitrogen oxide, which react with the water molecules in the atmosphere to produce acids.<sup>[64]</sup> Some governments have made efforts since the 1970s to reduce the release of sulfur dioxide and nitrogen oxide into the atmosphere. The main source of sulfur and nitrogen compounds that result in acid rain are anthropogenic, but nitrogen oxides can also be produced naturally by lightning strikes and sulphur dioxide

is produced by volcanic eruptions.<sup>[65]</sup> Acid rain can have harmful effects on plants, aquatic ecosystems and infrastructure.<sup>[66][67]</sup>

Carbon dioxide concentrations in the atmosphere have increased since the 1850s due anthropogenic influences (emissions of greenhouse gases).<sup>[68]</sup> This leads to ocean acidification and is another form of water pollution from atmospheric contributions.<sup>[69]</sup>

Water pollution may be analyzed through several broad categories of methods: physical, chemical and biological. Some methods may be conducted in situ, without sampling, such as temperature. Others involve collection of samples, followed by specialized analytical tests in the laboratory. Standardized, validated analytical test methods, for water and wastewater samples have been published.<sup>[70]</sup>

Common physical tests of water include temperature, Specific conductance or electrical conductance (EC) or conductivity, solids concentrations (e.g., total suspended solids (TSS)) and turbidity. Water samples may be examined using analytical chemistry methods. Many published test methods are available for both organic and inorganic compounds. Frequently used parameters that are quantified are pH, BOD,<sup>[71]:102</sup> chemical oxygen demand (COD),<sup>[71]:104</sup> dissolved oxygen (DO), total hardness, nutrients (nitrogen and phosphorus compounds, e.g. nitrate and orthophosphates), metals (including copper, zinc, cadmium, lead and mercury), oil and grease, total petroleum hydrocarbons (TPH), surfactants and pesticides.

The use of a biomonitor or bioindicator is described as biological monitoring. This refers to the measurement of specific properties of an organism to obtain information on the surrounding physical and chemical environment.<sup>[72]</sup> Biological testing involves the use of plant, animal or microbial indicators to monitor the health of an aquatic ecosystem. They are any biological species or group of species whose function, population, or status can reveal what degree of ecosystem or environmental integrity is present.<sup>[73]</sup> One example of a group of bio-indicators are the copepods and other small water crustaceans that are present in many water bodies. Such organisms can be monitored for changes (biochemical, physiological, or behavioral) that may indicate a problem within their ecosystem.

### III. RESULTS

Water pollution is a major global environmental problem because it can result in the degradation of all aquatic ecosystems – fresh, coastal, and ocean waters.<sup>[74]</sup> The specific contaminants leading to pollution in water include a wide spectrum of chemicals, pathogens, and physical changes such as elevated temperature. While many of the chemicals and substances that are regulated may be naturally occurring (calcium, sodium, iron, manganese, etc.) the concentration usually determines what is a natural component of water and what is a contaminant. High concentrations of naturally occurring substances can have negative impacts on aquatic flora and fauna. Oxygen-depleting substances may be natural materials such as plant matter (e.g. leaves and grass) as well as man-made chemicals. Other natural and anthropogenic substances may cause turbidity (cloudiness) which blocks light and disrupts plant growth, and clogs the gills of some fish species.<sup>[75]</sup> Nitrogen pollution can cause eutrophication, especially in lakes. Eutrophication is an increase in the concentration of chemical nutrients in an ecosystem to an extent that increases the primary productivity of the ecosystem. Subsequent negative environmental effects such as anoxia (oxygen depletion) and severe reductions in water quality may occur.<sup>[1]:131</sup> This can harm fish and other animal populations. Eutrophication is the process by which an entire body of water, or parts of it, becomes progressively enriched with minerals and nutrients, particularly nitrogen<sup>[78]</sup> and phosphorus. It has also been defined as "nutrient-induced increase in phytoplankton productivity".<sup>[79]:459</sup> Water bodies with very low nutrient levels are termed oligotrophic and those with moderate nutrient levels are termed mesotrophic. Advanced eutrophication may also be referred to as dystrophic and hypertrophic conditions.<sup>[80]</sup> Eutrophication can affect freshwater or salt water systems. In freshwater ecosystems it is almost always caused by excess phosphorus.<sup>[81]</sup> In coastal waters on the other hand, the main contributing nutrient is more likely to be nitrogen, or nitrogen and phosphorus together. This depends on the location and other factors.<sup>[82][83]</sup>

Municipal wastewater can be treated by centralized sewage treatment plants, decentralized wastewater systems, nature-based solutions<sup>[86]</sup> or in onsite sewage facilities and septic tanks. For example, waste stabilization ponds are a low cost treatment option for sewage, particularly for regions with warm climates.<sup>[1]:182</sup> UV light (sunlight) can be used to degrade some pollutants in waste stabilization ponds (sewage lagoons).<sup>[87]</sup> The use of safely managed sanitation services would prevent water pollution caused by lack of access to sanitation.<sup>[35]</sup>

Well-designed and operated systems (i.e., with secondary treatment stages or more advanced tertiary treatment) can remove 90 percent or more of the pollutant load in sewage.<sup>[88]</sup> Some plants have additional systems to remove nutrients and pathogens. While such advanced treatment techniques will undoubtedly reduce the discharges of micropollutants, they can also result in large financial costs, as well as environmentally undesirable increases in energy consumption and greenhouse gas emissions.<sup>[89]</sup>

Sewer overflows during storm events can be addressed by timely maintenance and upgrades of the sewerage system. In the US, cities with large combined systems have not pursued system-wide separation projects due to the high cost,<sup>[90]</sup> but have implemented partial separation projects and green infrastructure approaches.<sup>[91]</sup> In some cases municipalities have installed additional CSO storage facilities<sup>[92]</sup> or expanded sewage treatment capacity.<sup>[93]</sup>

Industrial wastewater treatment describes the processes used for treating wastewater that is produced by industries as an undesirable by-product. After treatment, the treated industrial wastewater (or effluent) may be reused or released to a sanitary sewer or to a surface water in the environment. Some industrial facilities generate wastewater that can be treated in sewage treatment plants. Most industrial processes, such as petroleum refineries, chemical and petrochemical plants have their own specialized facilities to treat their wastewaters so that the pollutant concentrations in the treated wastewater comply with the regulations regarding disposal of wastewaters into sewers or into rivers, lakes or oceans.<sup>[94]:1412</sup> This applies to industries that generate wastewater with high concentrations of organic matter (e.g. oil and grease), toxic pollutants (e.g. heavy metals, volatile organic compounds) or nutrients such as ammonia.<sup>[95]:180</sup> Some industries install a pre-treatment system to remove some pollutants (e.g., toxic compounds), and then discharge the partially treated wastewater to the municipal sewer system

Agricultural wastewater treatment is a farm management agenda for controlling pollution from confined animal operations and from surface runoff that may be contaminated by chemicals in fertilizer, pesticides, animal slurry, crop residues or irrigation water. Agricultural wastewater treatment is required for continuous confined animal operations like milk and egg production. It may be performed in plants using mechanized treatment units similar to those used for industrial wastewater. Where land is available for ponds, settling basins and facultative lagoons may have lower operational costs for seasonal use conditions from breeding or harvest cycles. Animal slurries are usually treated by containment in anaerobic lagoons before disposal by spray or trickle application to grassland. Constructed wetlands are sometimes used to facilitate treatment of animal wastes.

#### IV. CONCLUSIONS

Aquatic toxicology is the study of the effects of manufactured chemicals and other anthropogenic and natural materials and activities on aquatic organisms at various levels of organization, from subcellular through individual organisms to communities and ecosystems.<sup>[1]</sup> Aquatic toxicology is a multidisciplinary field which integrates toxicology, aquatic ecology and aquatic chemistry.<sup>[1]</sup>

This field of study includes freshwater, marine water and sediment environments. Common tests include standardized acute and chronic toxicity tests lasting 24–96 hours (acute test) to 7 days or more (chronic tests). These tests measure endpoints such as survival, growth, reproduction, that are measured at each concentration in a gradient, along with a control test.<sup>[2]</sup> Typically using selected organisms with ecologically relevant sensitivity to toxicants and a well-established literature background. These organisms can be easily acquired or cultured in lab and are easy to handle.<sup>[3]</sup>

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