The Flint Water Crisis and Its Health Consequences

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THE FLINT WATER CRISIS AND ITS HEALTH CONSEQUENCES

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BRIEFING

The water crisis that gripped the city of Flint, Michigan, in 2014 and 2015—and which is still felt to the present day—became one of the most notorious and scandalous public health disasters in recent United States history. The immediate cause was the contamination of the municipal water supply with toxic lead and dangerous bacteria, but the true cause is widely considered to be colossal mismanagement and unsound cost-cutting measures imposed on the city. Compounding the scandal is the fact that the population of Flint is disproportionately poor and African-American, suggesting to many critics that such mismanagement might not have occurred in a place with a wealthier, whiter population. Although the most acute health consequences of the crisis may be over, the long-term effects, particularly from the lead exposure, may take years to emerge. *See also: Environmental toxicology; Lead; Water supply engineering*

According to the U.S. Census Bureau, Flint is a city of almost 100,000 people where more than 40 percent live below the poverty line. The General Motors automobile factory located in Flint was for many years the company's

Figure 1:

Water can be contaminated by chemicals or other foreign substances that are detrimental to human health. The water crisis in Flint, Michigan, involved the contamination of the municipal water supply with toxic lead and dangerous bacteria.
(Credit: National Institute of Environmental Health Sciences, National Institutes of Health)

largest, but the weakness of the American auto industry caused a decline in the city's fortunes starting in the 1980s. Because of Flint's poor finances, it was put into receivership and managed by state officials between 2011 and 2015. One of the decisions made during this time was to reduce the city's water bill by switching suppliers from the Detroit Water and Sewerage Department (DWSD) to the Karegnondi Water Authority, via a new tunnel to be bored to Lake Huron. Flint stopped obtaining water from the DWSD in April 2014, but because the new Lake Huron supply was not yet available, the city adopted an interim measure of drawing water from the nearby Flint River. Although the Flint River had served as the city's backup water source for many years and had been the primary source of water early in the 20th century, it had historically suffered from poor quality, especially in more recent decades. Runoff in the Flint River watershed contained a variety of pollutants, including industrial compounds, pesticides, fertilizers, and fecal bacteria. Those problems, which officials seem to have addressed inadequately, soon translated into a variety of health threats for Flint's citizens.

See also: Lake; River; Water-borne disease; Water resources

Shortly after the switchover to Flint River water, city residents began to complain that their water had an unpleasant smell, taste, and orange discoloration. In August 2014, tests detected fecal coliform bacteria (E. coli) in the water reaching some Flint neighborhoods, leading to the first of two temporary advisories that the water be boiled before use. Intestinal E. coli infections can cause severe diarrhea and dehydration, with complications such as kidney failure, and they are most dangerous for children, pregnant women, and people with weakened immune systems. In response to the coliform bacteria reports, Flint officials increased the amount of antibacterial chlorine used to treat the water.

See also: Escherichia; Escherichia coli outbreaks; Water treatment

Researchers from the Hurley Medical Center announced in September 2015 that the number of children in Flint with excess blood lead levels had doubled since the switch to Flint River water, and that the levels had tripled in neighborhoods with the highest lead contamination in their water.

The levels of chlorine and other corrosive compounds in the Flint River water caused further problems. By October 2014, General Motors had stopped using Flint's municipal water out of concern that it corroded sensitive engine parts. More significantly, the corrosiveness of the water leached lead out of old pipes used throughout the city. Lead poisoning poses serious and even fatal threats to the nervous system and kidneys at every age, but high lead levels are especially dangerous for children under the age of six, whose physical and mental development may be permanently stunted. The U.S. Environmental Protection Agency (EPA) sets a limit of 15 parts per billion for lead in drinking water, but because lead and other heavy metals accumulate within the body, no level of lead exposure is considered perfectly safe. In Flint, tests showed that the lead levels in the water in some homes was many times the EPA-recommended maximum. The extent of the lead contamination problem in Flint's water at its worst is uncertain and controversial, but a preliminary report issued by a research team from Virginia Tech found that 40% of homes in Flint might have high lead levels. Researchers from the Hurley Medical Center announced in September 2015 that the number of children in Flint with excess blood lead levels had doubled since the switch to Flint River water, and that the levels had tripled in neighborhoods with the highest lead contamination in their water. The final version of an EPA report on testing at three Flint homes issued in November 2015 noted that "even with corrosion control treatment in place in the future, physical disturbances will be capable of dislodging the high lead-bearing scale and sediment from non-lead pipes as well as lead pipes."

See also: Childhood lead exposure and lead toxicity; Chlorine; Corrosion; Poison

Health officials noted that the number of cases of Legionnaires disease (Legionella) around Flint rose atypically during 2014 and 2015, claiming 10 lives. The Michigan Department of Health and Human Services maintains that no clear connection between this outbreak and the Flint water crisis has been established, but the family of one of the Legionella victims has filed a $100 million lawsuit against Michigan Department of Environmental Quality officials and a regional medical center.

See also: Legionnaires' disease; Public health

What makes the Flint water crisis a scandal is the evidence that mismanagement by city and state officials was ultimately to blame for most of the problems and health consequences suffered by the citizens. The final report of the Flint Water Advisory Task Force, released March 23, 2016, described the crisis as "a story of government failure, intransigence, unpreparedness, delay, inaction, and environmental injustice." It faulted Michigan state agencies for failing to enforce drinking water regulations in Flint, failing to take appropriate measures to prevent the foreseeable pipe corrosion problems, and discrediting efforts to bring attention to the early evidence of tainted water and lead contamination. It also blamed other public officials, including the state governor, for not reversing the bad decisions made in the management of the crisis more promptly. Criminal charges are pending against more than a dozen state and local officials, including multiple felony charges against some of the state-appointed emergency managers.

Flint returned to drawing water from its Detroit source in October 2015. Because of damage to corroded plumbing, some residents still filter their water to remove impurities or use bottled water for drinking, cooking, and routine hygiene. Recent tests of the water in Flint homes generally find that the quality is well within federal safety standards, but the trust of Flint's citizens in their water has been slow to rebound.

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ADDITIONAL READINGS:

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- **U.S. Environmental Protection Agency: Flint Drinking Water Documents**
- **U.S. Environmental Protection Agency: Flint Safe Drinking Water Task Force Draft Lead in Drinking Water — Preliminary Assessment**

WATER POLLUTION

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ARTICLE

CONTENT:

KEY CONCEPTS

- Water pollution refers to a variety of human activities that affect water quality in ways that are harmful to the health of humans, aquatic species, or ecosystems.
- Contaminants can enter the water from point sources, which are single locations, or nonpoint sources, which are too diffuse to pinpoint.
- Researchers can assess the toxicity of contaminants from wastewater discharges into receiving waters by the whole-effluent approach or the chemical-specific approach.
- Water pollution can affect the aquatic ecosystem either by causing changes in the chemical and physical qualities of the water (such as dissolved oxygen, pH, temperature, and suspended solids), thus affecting species sensitive to those factors, or by directly affecting the health of exposed aquatic organisms.

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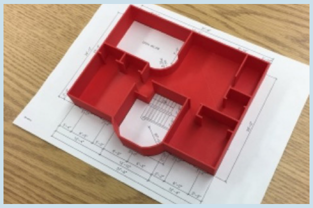
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Water pollution – a change in the chemical, physical, biological, and radiological quality of water that is injurious to its existing, intended, or potential uses.

Pollution of groundwater, rivers, lakes, wetlands, estuaries, and oceans can make the water we drink and fish we eat unsafe as well as threaten the health of humans, plants, and wildlife. Water pollution generally refers to human-induced (anthropogenic) changes to water quality, such as the discharge of toxic chemicals from a pipe or the release of livestock waste into a water body is considered pollution **(Fig. 2).** Conversely, nutrients that originate from animals in the wild (for example, in the wastes from a herd of elk) and toxins that originate from natural processes (for example, from dinoflagellate blooms in red tides) are not considered pollution. Regulations for curbing water pollution levels are based in part on determinations about how harmful the contaminants or their derivatives might be.

Figure 2:
Point-source pollution into a river. (Credit: Toa55/Getty Images)

CONTAMINANTS

The principal contaminants of water are shown in **(Table 1).** These include toxic chemicals, nutrients and biodegradable organics, and bacterial and viral pathogens. These include toxic chemicals, nutrients and biodegradable organics, and bacterial and viral pathogens.

See also: Pathogen

POINT SOURCES

Sources of water pollution are generally divided into two categories. The first is point-source pollution, in which contaminants are discharged from a single location **(Fig. 2).** Sewage pipes and the 2010 Gulf oil spill are examples of point-source pollution.

Since the passage of the Clean Water Act in 1972, there has been considerable progress in reducing the amount of pollution originating from municipal and industrial point sources. Most wastewater treatment plants are designed to accomplish the removal of suspended solids, biodegradable organics, and pathogenic organisms. The impact of the discharge of biodegradable organics can be measured in terms of the buildup of sludge deposits and depletion of the dissolved oxygen resources of water bodies. This situation led to requirements for secondary treatment of wastewaters. Similarly, concern over the toxicity caused by the discharge of heavy metals in treated effluents led to the development of effective pretreatment programs.

Table 1:
Contaminants of concern found in point and non-point discharges to water bodies

CONTAMINANTS	CONCERN
Atmospheric pollutants	Acid rain leads to acid (low pH) conditions; deposition of potentially toxic constituents
Biodegradable organics	Depletion of natural oxygen resources and the development of septic conditions
Current-use pesticides	Toxicity to aquatic biota
Dissolved inorganics (such as total dissolved solids)	Inorganic constituents added by usage; reclamation and reuse applications
Heat	Growth of undesirable aquatic life; threat to sensitive life forms, upset of ecological balances
Heavy metals	Toxicity to aquatic biota; many metals are also classified as priority pollutants
Nutrients (nitrogen and phosphorus)	Growth of undesirable aquatic life; eutrophication
Pathogenic organisms	Communicable diseases
Priority organic pollutants	Suspected carcinogenicity, mutagenicity, teratogenicity, or high acute toxicity; many priority pollutants resist conventional treatment methods (known as refractory organics); long-term effects are unknown
Suspended solids (inorganic and organic)	Siltation; formation of sludge deposits and anaerobic conditions

NONPOINT SOURCES

The second category is nonpoint-source or diffuse pollution, referring to all of the other discharges that deliver contaminants to water bodies. Acid rain and unconfined runoff from agricultural or urban areas are examples of nonpoint-source pollution **(Fig. 3).**

See also: [*Acid rain*]

Reducing contamination from nonpoint sources has been considerably more difficult, in part because these inputs are widely distributed and highly variable. To better understand the relationship between water quality and chemical use, land use, climate geology, topography, and soils, Congress appropriated funds for the National Water-Quality Assessment (NAWQA) Program in 1991. The NAWQA Program is an ongoing investigation by the U.S. Geological Survey in river basins and aquifers around the country

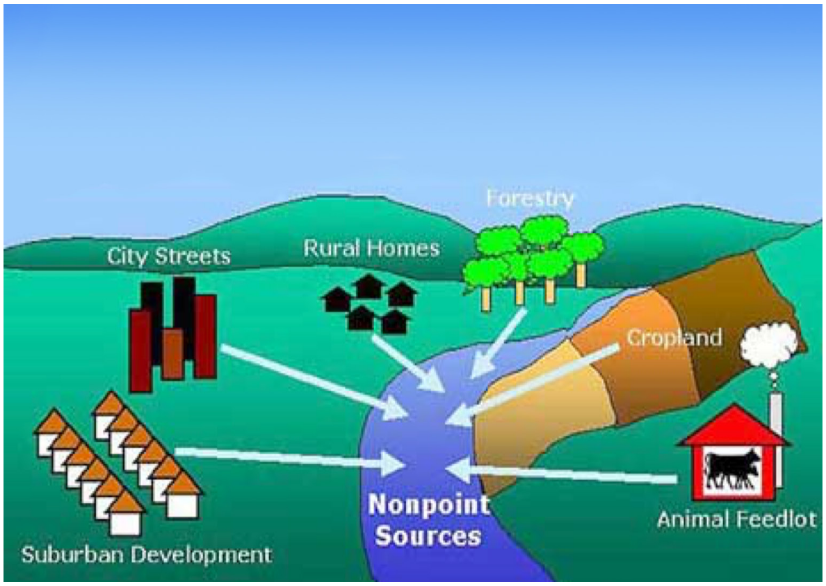

Figure 3:
Examples of nonpoint-source pollution. (NOAA)

TRANSPORT AND TRANSFORMATION PROCESSES

Contaminants discharged to water bodies are subject to a variety of transport and transformation processes and operations that can alter their composition. The physical, chemical, and biological processes that control the fate of the contaminants discharged to water bodies are numerous and varied. It is convenient to divide them into transport processes that affect all water-quality parameters in the same way and fate and transformation processes which are constituent-specific.

After initial dilution, contaminants discharged to a water body are transported by two basic processes, advection and dispersion. Advection refers to the transport of a constituent resulting from the flow of the water in which the constituent is dissolved or suspended. Turbulent velocity fluctuations, in conjunction with concentration gradients and molecular diffusion, lead to a mass transport phenomenon called dispersion.

See also: [*Environmental fluid mechanics; Stream transport and deposition*]

The principal fate and transformation processes that affect contaminants discharged to the environment are operative in most water bodies **(Table 2)**. The relative importance of individual fate and transformation processes will be site-specific and will depend on the water-quality parameter under evaluation. For example, deoxygenation brought about by bacterial activity, surface reaeration, sediment oxygen demand, and photosynthesis and respiration are of major importance in assessing the oxygen resources of a stream.

Table 2:

Fate and transformation processes affecting contaminants discharged to water bodies

PROCESS	CONSTITUENTS AFFECTED
Adsorption and desorption	Metals; trace organics; NH_4^+; PO_4^{-3}
Bacterial conversion, aerobic and anaerobic	Biochemical oxygen demand; nitrification; denitrification; sulfate reduction; anaerobic fermentation (in bottom sediments); conversion of priority organic pollutants
Chemical reactions (hydrolysis, ion exchange, oxidation-reduction, and so on)	Decomposition of organic compounds; specific ion exchange; element substitution
Filtration	Suspended matter; colloidal particles
Flocculation	Suspended matter; colloidal particles
Gas absorption and desorption	O_2; CO_2; CH_4; NH_3; H_2S
Natural decay	Plants; animals; protists (algae, fungi, protozoa); eubacteria (most bacteria); archaebacteria; viruses; radioactive substances
Photochemical reactions	Oxidation of inorganic and organic compounds
Photosynthesis and respiration	Algae, duckweed; submerged macrophites; NH_4^+; PO_4^{-3}; pH
Sedimentation	Suspended solids
Sediment oxygen demand	O_2, particulate biochemical oxygen demand
Surface reaeration	O_2; CO_2
Volatilization	Volatile organic compounds; NH_3; CH_4; H_2S, other gases

HARMFUL EFFECTS ON HUMAN HEALTH

Water pollution can threaten human health when pollutants enter the body via skin exposure or through the direct consumption of contaminated food or drinking water. For example, many states have issued fish consumption advisories following the detection of mercury in fish tissues. Other priority pollutants, including dichlorodiphenyl trichloroethane (DDT) and polychlorinated biphenyls (PCBs), persist in the natural environment and bioaccumulate in the tissues of aquatic organisms. These persistent organic pollutants are transferred up the food chain (in a process called biomagnification), and they can reach levels of concern in fish species that are eaten by humans. Finally, bacterial and viral pathogens can pose a public health risk for those who drink contaminated water or eat raw shellfish from polluted water bodies.

See also: Environmental toxicology; Food web; Persistent, bioaccumulative, and toxic pollutants

HARMFUL EFFECTS ON AQUATIC SPECIES

Contaminants have a significant impact on aquatic ecosystems; for example, enrichment of water bodies with nutrients (principally nitrogen and phosphorus) can result in the growth of algae and other aquatic plants that shade or clog streams. If wastewater containing biodegradable organic matter is discharged into a stream with inadequate dissolved oxygen, the water downstream of the point of discharge (typically an outfall) will become anaerobic and will be turbid and dark. Settleable solids, if present, will be deposited on the streambed, and anaerobic decomposition will occur. Where the dissolved-oxygen concentration in the stream is zero, a zone of putrefaction will occur with the production of hydrogen sulfide, ammonia, and other odorous gases. Because many fish species require a minimum of 4–5 mg of dissolved oxygen per liter of water, they will be unable to survive in this portion of the stream. In addition to reductions in dissolved oxygen, aquatic species are sensitive to changes in other physical habitat factors, including pH, temperature, and suspended solids.

See also: Freshwater ecosystem

Direct exposure to toxic chemicals is also a health concern for individual aquatic plants and animals. For example, pesticides are used to kill undesirable or nuisance organisms in many urban and agricultural areas. These chemicals are frequently transported to lakes and rivers via runoff, and they can have unintended and harmful effects on aquatic life. Obvious signs of contaminant exposure in fish from polluted environments include lesions, tumors, and skeletal deformities. Toxic chemicals have also been shown to reduce the growth, survival, reproductive output, and disease resistance of exposed organisms. These effects, while subtle, can have important consequences for the viability of aquatic populations and communities.

See also: Pesticide

Aquatic species are sensitive to changes in other physical habitat factors, including pH, temperature, and suspended solids.

EFFLUENT DISCHARGE

Wastewater discharges are most commonly controlled through effluent standards and discharge permits. Discharge permits are issued with limits on the quantity and quality of effluents. These limits are based on a case-by-case evaluation of potential environmental impacts and, in the case of multiple dischargers, on waste load allocation studies aimed at distributing the available assimilative capacity of the water body. Discharge permits are designed as an enforcement tool, with the ultimate goal of meeting ambient water-quality standards.

WATER-QUALITY STANDARDS AND CRITERIA

Water-quality standards are sets of qualitative and quantitative criteria designed to maintain or enhance the quality of receiving waters. Receiving waters are divided into several classes depending on their uses, existing or intended, with different sets of criteria designed to protect uses such as drinking water supply, bathing, boating, freshwater and shellfish harvesting, and outdoor sports for seawater.

TOXICITY STUDIES

For toxic compounds, chemical-specific or whole-effluent toxicity studies are used to develop standards and criteria. In the chemical-specific approach, individual criteria are used for each toxic chemical detected in the wastewater. Criteria can be developed to protect aquatic life against acute and chronic effects and to safeguard humans against deleterious health effects, including cancer. The chemical-specific approach, however, does not consider the possible additive, antagonistic, or synergistic effects of multiple chemicals. The biological availability of the compound, which depends on its form in the wastewater, is also not considered in this approach.

The whole-effluent toxicity approach can be used to overcome the shortcomings of the chemical-specific approach. In the whole-effluent approach, toxicity or bioassay tests are used to determine the concentration at which the wastewater induces acute or chronic toxicity effects. In bioassay testing, selected organisms are exposed to effluent diluted in various ratios with samples of receiving water. At various points during the test, the organisms affected by various effects, such as lower reproduction rates, reduced growth, or death, are quantified. To protect aquatic life discharge limits are established based on the results of the tests.

See also: Hazardous waste; Sewage treatment

TEST YOUR UNDERSTANDING

1. Suggest three examples that show how water pollution can affect the intended use of a body of water.

2. What makes control of nonpoint source pollution challenging?

3. Critical Thinking: What is the major advantage of the whole-effluent approach compared with the chemical-specific approach in studying the toxicity of wastewater?

4. Critical Thinking: How can a high yet nontoxic concentration of nitrogen and phosphorus result in a fish kill?

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- **U.S. Geological Survey (USGS): National Water-Quality Assessment (NAWQA) Program**