



Pollution

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Pollution is the introduction of contaminants into the natural environment that cause adverse change.^[1] Pollution can take the form of chemical substances or energy, such as noise, heat or light. Pollutants, the components of pollution, can be either foreign substances/energies or naturally occurring contaminants. Pollution is often classed as point source or nonpoint source pollution.



The litter problem on the coast of Guyana, 2010

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Ancient cultures

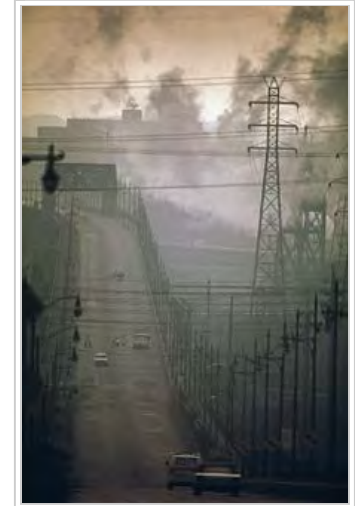
Air pollution has always accompanied civilizations. Pollution started from prehistoric times when man created the first fires. According to a 1983 article in the journal *Science*, "soot found on ceilings of prehistoric caves provides ample evidence of the high levels of pollution that was associated with inadequate ventilation of open fires."^[2] Metal forging appears to be a key turning point in the creation of

significant air pollution levels outside the home. Core samples of glaciers in Greenland indicate increases in pollution associated with Greek, Roman and Chinese metal production,^[3] but at that time the pollution was comparatively small and could be handled by nature.

Urban pollution

The burning of coal and wood, and the presence of many horses in concentrated areas made the cities the cesspools of pollution. The Industrial Revolution brought an infusion of untreated chemicals and wastes into local streams that served as the water supply. King Edward I of England banned the burning of sea-coal by proclamation in London in 1272, after its smoke became a problem.^{[4][5]} But the fuel was so common in England that this earliest of names for it was acquired because it could be carted away from some shores by the wheelbarrow.

It was the industrial revolution that gave birth to environmental pollution as we know it today. London also recorded one of the earlier extreme cases of water quality problems with the Great Stink on the Thames of 1858, which led to construction of the London sewerage system soon afterward. Pollution issues escalated as population growth far exceeded view ability of neighborhoods to handle their waste problem. Reformers began to demand sewer systems, and clean water.^[6]



Air pollution in the US, 1973

In 1870, the sanitary conditions in Berlin were among the worst in Europe. August Bebel recalled conditions before a modern sewer system was built in the late 1870s:

"Waste-water from the houses collected in the gutters running alongside the curbs and emitted a truly fearsome smell. There were no public toilets in the streets or squares. Visitors, especially women, often became desperate when nature called. In the public buildings the sanitary facilities were unbelievably primitive....As a metropolis, Berlin did not emerge from a state of barbarism into civilization until after 1870."^[7]

The primitive conditions were intolerable for a world national capital, and the Imperial German government brought in its scientists, engineers and urban planners to not only solve the deficiencies but to forge Berlin as the world's model city. A British expert in 1906 concluded that Berlin represented "the most complete application of science, order and method of public life," adding "it is a marvel of civic administration, the most modern and most perfectly organized city that there is."^[8]

The emergence of great factories and consumption of immense quantities of coal gave rise to unprecedented air pollution and the large volume of industrial chemical discharges added to the growing load of untreated human waste. Chicago and Cincinnati were the first two American cities to enact laws ensuring cleaner air in 1881. Pollution became a major issue in the United States in the early twentieth century, as progressive reformers took issue with air pollution caused by coal burning, water pollution caused by bad sanitation, and street pollution caused by the 3 million horses who worked in American

cities in 1900, generating large quantities of urine and manure. As historian Martin Melosi notes, The generation that first saw automobiles replacing the horses saw cars as "miracles of cleanliness."^[9] By the 1940s, however, automobile-caused smog was a major issue in Los Angeles.^[10]

Other cities followed around the country until early in the 20th century, when the short lived Office of Air Pollution was created under the Department of the Interior. Extreme smog events were experienced by the cities of Los Angeles and Donora, Pennsylvania in the late 1940s, serving as another public reminder.^[11] Air pollution would continue to be a problem in England, especially later during the industrial revolution, and extending into the recent past with the Great Smog of 1952.

Awareness of atmospheric pollution spread widely after World War II, with fears triggered by reports of radioactive fallout from atomic warfare and testing.^[12] Then a non-nuclear event, The Great Smog of 1952 in London, killed at least 4000 people.^[13] This prompted some of the first major modern environmental legislation, The Clean Air Act of 1956.

Pollution began to draw major public attention in the United States between the mid-1950s and early 1970s, when Congress passed the Noise Control Act, the Clean Air Act, the Clean Water Act and the National Environmental Policy Act.^[14]

Severe incidents of pollution helped increase consciousness. PCB dumping in the Hudson River resulted in a ban by the EPA on consumption of its fish in 1974. Long-term dioxin contamination at Love Canal starting in 1947 became a national news story in 1978 and led to the Superfund legislation of 1980.^[15] The pollution of industrial land gave rise to the name brownfield, a term now common in city planning.

The development of nuclear science introduced radioactive contamination, which can remain lethally radioactive for hundreds of thousands of years. Lake Karachay, named by the Worldwatch Institute as the "most polluted spot" on earth, served as a disposal site for the Soviet Union throughout the 1950s and 1960s. Second place may go to the area of Chelyabinsk Russian as the "Most polluted place on the planet".^[16]

Nuclear weapons continued to be tested in the Cold War, especially in the earlier stages of their development. The toll on the worst-affected populations and the growth since then in understanding about the critical threat to human health posed by radioactivity has also been a prohibitive complication associated with nuclear power. Though extreme care is practiced in that industry, the potential for disaster suggested by incidents such as those at Three Mile Island and Chernobyl pose a lingering specter of public mistrust. Worldwide publicity has been intense on those disasters.^[17] Widespread support for test ban treaties has ended almost all nuclear testing in the atmosphere.^[18]

International catastrophes such as the wreck of the Amoco Cadiz oil tanker off the coast of Brittany in 1978 and the Bhopal disaster in 1984 have demonstrated the universality of such events and the scale on which efforts to address them needed to engage. The borderless nature of atmosphere and oceans inevitably resulted in the implication of pollution on a planetary level with the issue of global warming. Most recently the term persistent organic pollutant (POP) has come to describe a group of chemicals such as PBDEs and PFCs among others. Though their effects remain somewhat less well understood owing to



Smog Pollution in Taiwan

a lack of experimental data, they have been detected in various ecological habitats far removed from industrial activity such as the Arctic, demonstrating diffusion and bioaccumulation after only a relatively brief period of widespread use.

A much more recently discovered problem is the Great Pacific Garbage Patch, a huge concentration of plastics, chemical sludge and other debris which has been collected into a large area of the Pacific Ocean by the North Pacific Gyre. This is a less well known pollution problem than the others described above, but nonetheless has multiple and serious consequences such as increasing wildlife mortality, the spread of invasive species and human ingestion of toxic chemicals. Organizations such as 5 Gyres have researched the pollution and, along with artists like Marina DeBris, are working toward publicizing the issue.

Pollution introduced by light at night is becoming a global problem, more severe in urban centres, but nonetheless contaminating also large territories, far away from towns.^[19]

Growing evidence of local and global pollution and an increasingly informed public over time have given rise to environmentalism and the environmental movement, which generally seek to limit human impact on the environment.

Forms of pollution

The major forms of pollution are listed below along with the particular contaminant relevant to each of them:

- **Air pollution:** the release of chemicals and particulates into the atmosphere. Common gaseous pollutants include carbon monoxide, sulfur dioxide, chlorofluorocarbons (CFCs) and nitrogen oxides produced by industry and motor vehicles. Photochemical ozone and smog are created as nitrogen oxides and hydrocarbons react to sunlight. Particulate matter, or fine dust is characterized by their micrometre size PM_{10} to $PM_{2.5}$.
- **Light pollution:** includes light trespass, over-illumination and astronomical interference.
- **Littering:** the criminal throwing of inappropriate man-made objects, unremoved, onto public and private properties.
- **Noise pollution:** which encompasses roadway noise, aircraft noise, industrial noise as well as high-intensity sonar.
- **Soil contamination** occurs when chemicals are released by spill or underground leakage. Among the most significant soil contaminants are hydrocarbons, heavy metals, MTBE,^[20] herbicides, pesticides and chlorinated hydrocarbons.
- **Radioactive contamination**, resulting from 20th century activities in atomic physics, such as nuclear power generation and nuclear weapons research, manufacture and deployment. (See alpha emitters and actinides in the environment.)
- **Thermal pollution**, is a temperature change in natural water bodies caused by human influence, such as use of water as coolant in a power plant.
- **Visual pollution**, which can refer to the presence of overhead power lines, motorway billboards, scarred landforms (as from strip mining), open storage of trash, municipal solid waste or space debris.



The Lachine Canal in Montreal, Quebec, Canada.

- Water pollution, by the discharge of wastewater from commercial and industrial waste (intentionally or through spills) into surface waters; discharges of untreated domestic sewage, and chemical contaminants, such as chlorine, from treated sewage; release of waste and contaminants into surface runoff flowing to surface waters (including urban runoff and agricultural runoff, which may contain chemical fertilizers and pesticides); waste disposal and leaching into groundwater; eutrophication and littering.
- Plastic pollution: involves the accumulation of plastic products in the environment that adversely affects wildlife, wildlife habitat, or humans.



Blue drain and yellow fish symbol used by the UK Environment Agency to raise awareness of the ecological impacts of contaminating surface drainage.

Pollutants

A pollutant is a waste material that pollutes air, water or soil. Three factors determine the severity of a pollutant: its chemical nature, the concentration and the persistence.

Cost of pollution

Pollution has cost. Manufacturing activities that cause air pollution impose health and clean-up costs on the whole society, whereas the neighbors of an individual who chooses to fire-proof his home may benefit from a reduced risk of a fire spreading to their own houses. If external costs exist, such as pollution, the producer may choose to produce more of the product than would be produced if the producer were required to pay all associated environmental costs. Because responsibility or consequence for self-directed action lies partly outside the self, an element of externalization is involved. If there are external benefits, such as in public safety, less of the good may be produced than would be the case if the producer were to receive payment for the external benefits to others.

Sources and causes



Air pollution produced by ships may alter clouds, affecting global temperatures.

Air pollution comes from both natural and human-made (anthropogenic) sources. However, globally human-made pollutants from combustion, construction, mining, agriculture and warfare are increasingly significant in the air pollution equation.^[21]

Motor vehicle emissions are one of the leading causes of air pollution.

^{[22][23][24]} China, United States, Russia, India^[25] Mexico, and Japan are the world leaders in air pollution emissions. Principal stationary pollution sources include chemical plants, coal-fired power plants, oil refineries,^[26] petrochemical plants, nuclear waste disposal activity, incinerators, large

livestock farms (dairy cows, pigs, poultry, etc.), PVC factories, metals production factories, plastics factories, and other heavy industry. Agricultural air pollution comes from contemporary practices which include clear felling and burning of natural vegetation as well as spraying of pesticides and herbicides^[27]

About 400 million metric tons of hazardous wastes are generated each year.^[28] The United States alone produces about 250 million metric tons.^[29] Americans constitute less than 5% of the world's population, but produce roughly 25% of the world's CO₂,^[30] and generate approximately 30% of world's waste.^{[31][32]} In 2007, China has overtaken the United States as the world's biggest producer of CO₂,^[33] while still far behind based on per capita pollution - ranked 78th among the world's nations.^[34]

In February 2007, a report by the Intergovernmental Panel on Climate Change (IPCC), representing the work of 2,500 scientists, economists, and policymakers from more than 120 countries, said that humans have been the primary cause of global warming since 1950. Humans have ways to cut greenhouse gas emissions and avoid the consequences of global warming, a major climate report concluded. But to change the climate, the transition from fossil fuels like coal and oil needs to occur within decades, according to the final report this year from the UN's Intergovernmental Panel on Climate Change (IPCC).^[35]

Some of the more common soil contaminants are chlorinated hydrocarbons (CFH), heavy metals (such as chromium, cadmium—found in rechargeable batteries, and lead—found in lead paint, aviation fuel and still in some countries, gasoline), MTBE, zinc, arsenic and benzene. In 2001 a series of press reports culminating in a book called *Fateful Harvest* unveiled a widespread practice of recycling industrial byproducts into fertilizer, resulting in the contamination of the soil with various metals. Ordinary municipal landfills are the source of many chemical substances entering the soil environment (and often groundwater), emanating from the wide variety of refuse accepted, especially substances illegally discarded there, or from pre-1970 landfills that may have been subject to little control in the U.S. or EU. There have also been some unusual releases of polychlorinated dibenzodioxins, commonly called *dioxins* for simplicity, such as TCDD.^[36]

Pollution can also be the consequence of a natural disaster. For example, hurricanes often involve water contamination from sewage, and petrochemical spills from ruptured boats or automobiles. Larger scale and environmental damage is not uncommon when coastal oil rigs or refineries are involved. Some sources of pollution, such as nuclear power plants or oil tankers, can produce widespread and potentially hazardous releases when accidents occur.

In the case of noise pollution the dominant source class is the motor vehicle, producing about ninety percent of all unwanted noise worldwide.

Effects

Human health

Adverse air quality can kill many organisms including humans. Ozone pollution can cause respiratory disease, cardiovascular disease, throat inflammation, chest pain, and congestion. Water pollution causes approximately 14,000 deaths per day, mostly due to contamination of drinking water by untreated sewage in developing countries. An estimated 500 million Indians have no access to a proper toilet,^{[40][41]} Over ten



An industrial area, with a power plant, south of Yangzhou's downtown, China

million people in India fell ill with waterborne illnesses in 2013, and 1,535 people died, most of them children.^[42] Nearly 500 million Chinese lack access to safe drinking water.^[43] A 2010 analysis estimated that 1.2 million people died prematurely each year in China because of air pollution.^[44] The WHO estimated in 2007 that air pollution causes half a million deaths per year in India.^[45] Studies have estimated that the number of people killed annually in the United States could be over 50,000.^[46]

Oil spills can cause skin irritations and rashes. Noise pollution induces hearing loss, high blood pressure, stress, and sleep disturbance. Mercury has been linked to developmental deficits in children and neurologic symptoms. Older people are majorly exposed to diseases induced by air pollution. Those with heart or lung disorders are at additional risk. Children and infants are also at serious risk. Lead and other heavy metals have been shown to cause neurological problems. Chemical and radioactive substances can cause cancer and as well as birth defects.

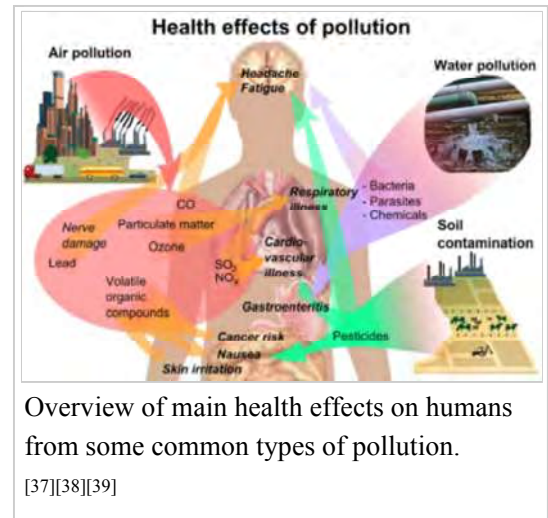
Environment

Pollution has been found to be present widely in the environment. There are a number of effects of this:

- Biomagnification describes situations where toxins (such as heavy metals) may pass through trophic levels, becoming exponentially more concentrated in the process.
- Carbon dioxide emissions cause ocean acidification, the ongoing decrease in the pH of the Earth's oceans as CO₂ becomes dissolved.
- The emission of greenhouse gases leads to global warming which affects ecosystems in many ways.
- Invasive species can out compete native species and reduce biodiversity. Invasive plants can contribute debris and biomolecules (allelopathy) that can alter soil and chemical compositions of an environment, often reducing native species competitiveness.
- Nitrogen oxides are removed from the air by rain and fertilise land which can change the species composition of ecosystems.
- Smog and haze can reduce the amount of sunlight received by plants to carry out photosynthesis and leads to the production of tropospheric ozone which damages plants.
- Soil can become infertile and unsuitable for plants. This will affect other organisms in the food web.
- Sulfur dioxide and nitrogen oxides can cause acid rain which lowers the pH value of soil.

Environmental health information

The Toxicology and Environmental Health Information Program (TEHIP)^[47] at the United States National Library of Medicine (NLM) maintains a comprehensive toxicology and environmental health web site that includes access to resources produced by TEHIP and by other government agencies and organizations. This web site includes links to databases, bibliographies, tutorials, and other scientific and



consumer-oriented resources. TEHIP also is responsible for the Toxicology Data Network (TOXNET)^[48] an integrated system of toxicology and environmental health databases that are available free of charge on the web.

TOXMAP is a Geographic Information System (GIS) that is part of TOXNET. TOXMAP uses maps of the United States to help users visually explore data from the United States Environmental Protection Agency's (EPA) Toxics Release Inventory and Superfund Basic Research Programs.

Worker productivity

A number of studies show that pollution has an adverse effect on the productivity of both indoor and outdoor workers.^{[49][50][51]}

Regulation and monitoring

To protect the environment from the adverse effects of pollution, many nations worldwide have enacted legislation to regulate various types of pollution as well as to mitigate the adverse effects of pollution.

Pollution control

Pollution control is a term used in environmental management. It means the control of emissions and effluents into air, water or soil. Without pollution control, the waste products from overconsumption, heating, agriculture, mining, manufacturing, transportation and other human activities, whether they accumulate or disperse, will degrade the environment. In the hierarchy of controls, pollution prevention and waste minimization are more desirable than pollution control. In the field of land development, low impact development is a similar technique for the prevention of urban runoff.



A litter trap catches floating waste in the Yarra River, east-central Victoria, Australia

Practices

- Recycling
- Reusing
- Waste minimisation
- Mitigating
- Preventing
- Compost

Pollution control devices

- Air pollution control
 - Thermal oxidizer
- Dust collection systems
 - Baghouses
 - Cyclones

- Electrostatic precipitators
- Scrubbers
 - Baffle spray scrubber
 - Cyclonic spray scrubber
 - Ejector venturi scrubber
 - Mechanically aided scrubber
 - Spray tower
 - Wet scrubber
- Sewage treatment
 - Sedimentation (Primary treatment)
 - Activated sludge biotreaters (Secondary treatment; also used for industrial wastewater)
 - Aerated lagoons
 - Constructed wetlands (also used for urban runoff)
- Industrial wastewater treatment
 - API oil-water separators^{[26][52]}
 - Biofilters
 - Dissolved air flotation (DAF)
 - Powdered activated carbon treatment
 - Ultrafiltration
- Vapor recovery systems
- Phytoremediation

Perspectives

The earliest precursor of pollution generated by life forms would have been a natural function of their existence. The attendant consequences on viability and population levels fell within the sphere of natural selection. These would have included the demise of a population locally or ultimately, species extinction. Processes that were untenable would have resulted in a new balance brought about by changes and adaptations. At the extremes, for any form of life, consideration of pollution is superseded by that of survival.

For humankind, the factor of technology is a distinguishing and critical consideration, both as an enabler and an additional source of byproducts. Short of survival, human concerns include the range from quality of life to health hazards. Since science holds experimental demonstration to be definitive, modern treatment of toxicity or environmental harm involves defining a level at which an effect is observable. Common examples of fields where practical measurement is crucial include automobile emissions control, industrial exposure (e.g. Occupational Safety and Health Administration (OSHA) PELs), toxicology (e.g. LD₅₀), and medicine (e.g. medication and radiation doses).



Air pollution control system, known as a Thermal oxidizer, decomposes hazard gases from industrial air streams at a factory in the United States of America.



A dust collector in Pristina, Kosovo



Gas nozzle with vapor recovery



A Mobile Pollution Check Vehicle in India.

"The solution to pollution is dilution", is a dictum which summarizes a traditional approach to pollution management whereby sufficiently diluted pollution is not harmful.^{[53][54]} It is well-suited to some other modern, locally scoped applications such as laboratory safety procedure and hazardous material release emergency management. But it assumes that the dilutant is in virtually unlimited supply for the application or that resulting dilutions are acceptable in all cases.

Such simple treatment for environmental pollution on a wider scale might have had greater merit in earlier centuries when physical survival was often the highest imperative, human population and densities were lower, technologies were simpler and their byproducts more benign. But these are often no longer the case. Furthermore, advances have enabled measurement of concentrations not possible before. The use of statistical methods in evaluating outcomes has given currency to the principle of probable harm in cases where assessment is warranted but resorting to deterministic models is impractical or infeasible. In addition, consideration of the environment beyond direct impact on human beings has gained prominence.

Yet in the absence of a superseding principle, this older approach predominates practices throughout the world. It is the basis by which to gauge concentrations of effluent for legal release, exceeding which penalties are assessed or restrictions applied. One such superseding principle is contained in modern hazardous waste laws in developed countries, as the process of diluting hazardous waste to make it non-hazardous is usually a regulated treatment process.^[55] Migration from pollution dilution to elimination in many cases can be confronted by challenging economical and technological barriers.

Greenhouse gases and global warming

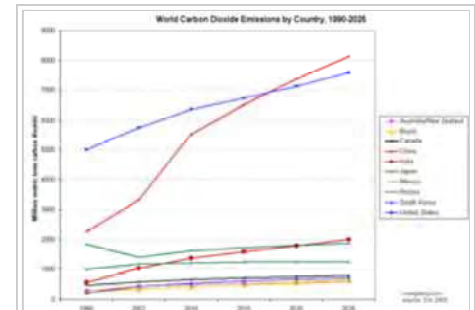
Carbon dioxide, while vital for photosynthesis, is sometimes referred to as pollution, because raised levels of the gas in the atmosphere are affecting the Earth's climate. Disruption of the environment can also highlight the connection between areas of pollution that would normally be classified separately, such as those of water and air. Recent studies have investigated the potential for long-term rising levels of atmospheric carbon dioxide to cause slight but critical increases in the acidity of ocean waters, and the possible effects of this on marine ecosystems.

Most polluted places in the developing world

The Blacksmith Institute, an international non-for-profit organization dedicated to eliminating life-threatening pollution in the developing world, issues an annual list of some of the world's worst polluted places.^[58]

See also

- Environmental health
- Marine pollution
- Pollutants



Historical and projected CO₂ emissions by country (as of 2005).

Source: Energy Information

Administration.^{[56][57]}

- Hazardous Substances Data Bank
- Regulation of greenhouse gases under the Clean Air Act
- Biological contamination
- Chemical contamination

Air pollution	Soil contamination	Water pollution	Other
<ul style="list-style-type: none"> ▪ Air dispersion modeling ▪ Arden Pope ▪ Atmospheric chemistry observational databases - links to freely available data. ▪ Climate change ▪ Emission standard ▪ Light pollution ▪ Greenhouse gas 	<ul style="list-style-type: none"> ▪ Environmental soil science ▪ List of solid waste treatment technologies ▪ List of waste management companies ▪ List of waste management topics 	<ul style="list-style-type: none"> ▪ Cruise ship pollution ▪ Marine debris ▪ Marine pollution ▪ Ship pollution ▪ Stormwater ▪ Wastewater ▪ Wastewater quality indicators 	<ul style="list-style-type: none"> ▪ Contamination control ▪ Earth Day ▪ Externality ▪ Genetic pollution ▪ Global warming ▪ Heat pollution ▪ List of environmental issues ▪ Noise health effects ▪ Space debris ▪ radioactivity

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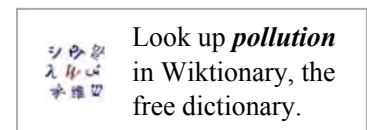
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- OEHHA proposition 65 list (http://www.oehha.ca.gov/prop65/prop65_list/Newlist.html)
- National Toxicology Program (<http://ntp-server.niehs.nih.gov/>) – from USA National Institutes of Health. Reports and studies on how pollutants affect people
- TOXNET (<http://toxnet.nlm.nih.gov/>) – NIH databases and reports on toxicology
- TOXMAP (<http://toxmap.nlm.nih.gov/>) – Geographic Information System (GIS) that uses maps of the United States to help users visually explore data from the United States Environmental Protection Agency (EPA) Toxics Release Inventory and Superfund Basic Research Programs
- EPA.gov (<http://www.epa.gov/superfund/>) – manages Superfund sites and the pollutants in them (CERCLA). Map the EPA Superfund (<http://toxmap.nlm.nih.gov/toxmap/main/index.jsp/>)
- Toxic Release Inventory (<http://www.epa.gov/tri/>) – tracks how much waste USA companies release into the water and air. Gives permits for releasing specific quantities of these pollutants each year. Map EPA's Toxic Release Inventory (<http://toxmap.nlm.nih.gov/toxmap/main/index.jsp>)
- Agency for Toxic Substances and Disease Registry (<http://www.atsdr.cdc.gov/index.html>) – Top 20 pollutants, how they affect people, what USA industries use them and the products in which they are found
- Toxicology Tutorials from the National Library of Medicine (<http://sis.nlm.nih.gov/enviro/toxtutor.html#toxtutor>) – resources to review human toxicology.



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