Pollution

What exactly is a pollutant? A working definition would be any material introduced into the environment above its normal "background" levels as a result of human activity. By this definition, any artificial chemical is a pollutant, since these materials are never found naturally.

It is often convenient to break pollutants down into several categories. One such scheme[1] would use the following groups:

pesticides	petroleum
synthetic industrial chemicals	heavy metals
radioisotopes	plastics
gases	others

A biocide is a chemical (or other agent) that kills living organisms. If the organism is a target (i.e. something we don't want around) we call a biocide used to kill it a pesticides. Pesticides are further classified either by their chemical composition (i.e. chlorinated hydrocarbons, organophosphates), their mode of action (i.e. nerve impulse inhibitors, anticoagulants), or target organisms (i.e. rodenticides, insecticides, herbicides). From a control standpoint, an ideal pesticide is deadly and long lasting. The deadlier it is, the less has to be used. The longer it lasts, the less frequently it has to be applied. The less used, the lower the cost. Of course, these attributes are the exact opposite of the characteristics we would like to see in the environment. We would like to see pesticides that are relatively benign and which break down quickly into non-toxic products. We normally think of pesticides as being spread on farms, but significant amounts are spread on forests (to control gypsy moths and other pests) or even cities (Los Angeles, to control the medfly, a pest of citrus).

It's scary to think that in the United States only a physician, with 6 years of advanced training, can obtain a license to prescribe small quantities of Penicillin, an antibiotic which, in retail quantities, could conceivably only harm one person; while virtually anyone can attend a PCO (pest control operator) school for 20 hours or so and be able to buy highly toxic chemicals by the ton.

Petroleum gets into ecosystems naturally, but a number of human activities dwarf these natural sources. Of course, since oil is a valuable commodity, much of this loss is accidental, such as when the *Exxon Valdez* struck a reef in Alaska. Even without catastrophic disasters such as this, however, many small sources of oil combine to form significant inputs to natural systems. Watch the motor oil (which leaks from cars) float on the surface of water draining from a shopping center during a rainstorm. And, of course,

[1]Modified from Cox, G.W. 1993. *Conservation Ecology.* Wm. C. Brown Publishers. 352 pp.

asphalt roads (and tar and oil spread on dirt roads to keep down dust) contribute oil to natural systems.

Only in the United States would we have regulations that require that a underground gasoline storage tank that is found to be leaking even small amounts of gasoline be dug up, and the soil around it treated as toxic waste, in a process which may cost thousands of dollars. At the same time, the county engineer may spread thousands of gallons of oil on dusty roads.

Synthetic industrial chemicals are an odd lot. They are not designed to be toxic, but rather to fill other, more benign roles. For instance, PCB (polychlorinated biphenyls) are chemicals which make good cooling oils for electrical transformers (which obviously can't use water). They hold heat well, and are non-conductive and inert. They are also toxic. They may be introduced to the environment when a transformer is damaged, catches on fire, or falls off a truck. These chemicals, unlike petroleum, which for the most part enters the environment accidentally, or pesticides, which are spread purposely, were designed to be long-lived.

Trichoroethylene (TCE) is an organic solvent (acetone, alcohol, xylene, benzene, etc. are also organic solvents). Organic solvents are good for removing oils and waxes from manufactured products such as metal parts or circuit boards. They are also used for cleaning parts when machinery is rebuilt. For some reason, TCE was spread in the area around the fairgrounds in Marietta some years ago. The fairgrounds are also the site of the drinking water wells for Marietta. The TCE has been detected in the drinking water; one pump at the fairgrounds pumps millions of gallons daily through an air stripper (a fancy name for a shower). As the water falls through the air, the TCE, which is more soluble in air than water, leaves the water and enters the air. The water passes into the Muskingum. This process removes the TCE from underground, and prevents it from flowing to the wells pumping drinking water. It may have to be continued for 25 years or so. I used to live in Lafayette, Indiana; they have the same problem with their water wells along the Wabash River there, and are solving it in the same way.

Heavy metals include cadmium, chromium, mercury, lead, zinc, and a small host of others. These metals are used in plating and finishing metals, in batteries, thermometers, switches, bullets, etc. Mercury is of particular concern. In addition to various industrial uses, it is also released into the air by some industrial processes, and it is used in gold mining. In the latter use, significant quantities often escape into rivers. In addition, mercury shows a strong tendency towards biomagnification, and its availability for uptake by organisms is increased by acid rain. Mercury causes neurological problems in humans (as does lead) and may cause reproductive failure in birds.

A fertilizer plant in Japan was responsible for releasing significant amounts of mercury into the ocean at Minamata, Japan[2]. In the 1950's; it was noticed that a significant number of fish were dying, and the cats began doing strange "dances" and dying. The people began to develop this disease some time later. It was a classic case of mercury poisoning through biomagnification through the fish. The villagers actually stormed the plant in protest in 1956, but the dumping wasn't stopped until 1968.

Plastics are basically very stable petroleum based products. Their major environmental impact lies in the fact that they are very long-lasting. At various scales, they physically entrap or choke animals. They are of particular concern in aquatic ecosystems, where the plastic can float for years. Large pieces of plastic, such as six-pack rings, abandoned fishing nets and lines, plastic bags, bottles, and jugs, may entangle animals and drown them. A common form of fishing in modern fleets are drift nets and long lines. These plastic structures may be many miles long; it is not uncommon for fishing fleets to lose their nets and lines. They continue to catch unsuspecting animals for some time. In fact, many animals are attracted to the nets by the fish already caught there. Most pathetic of all, perhaps, are loggerhead turtles, which normally feed on jellyfish. They may instead try to eat plastic bags and die from internal blockage of their digestive tracts.

Smaller plastic particles can also be a problem. They may be consumed by a wide range of organisms who will then die from blockages or malnutrition. These smaller particles come from the breakdown of larger chunks of plastic and from plastic pellets used in the plastics trade (the pellets are the "raw" plastic shipped from the plastic manufacturers to the companies which melt it down and mold it into finished products). Many of the plastic pellets are spilled in accidents or are dumped as waste. Small plastic particles now ring the oceans worldwide, and will probably last for a long time.

One of the world centers for plastic pellet production is the Ohio River valley, where petroleum supplies correspond with coal and cheap water-based transportation. Local companies such as Chevron produce such pellets and ship them on barges up and down the river.

Radioisotopes are unstable forms of many common materials. Virtually any chemical element has at least one radioactive form. These radioactive forms are called isotopes; the instability causes them to break down into smaller compounds. This breakdown releases energy (gamma rays) and particles (alpha, beta, neutrons, etc.) that we collectively call radiation. Radiation can damage the material in living cells; the DNA is particularly vulnerable to this damage. Damaged DNA can cause irregularities in the function of the cells, or it can trigger cancer. If the damaged DNA is in the sex organs, the damage can

[2]This account taken from The Cousteau Almanac, 1981, Doubleday & Company, Garden City, New York. 838 pp.

be passed on to the next generation. We need to note here that radioactivity is normal; we are exposed to it constantly. The sun generates a lot of it; much is screened out by the atmosphere. When you go up a mountain you are exposing yourself to greater radiation than you would receive at sea level.

Of major concern to us is the radiation produced when we take naturally radioactive materials such as uranium and concentrate the radioactive isotopes so that the radioactivity is strong enough to produce heat, which can then be used to make steam which is used to generate electricity. Nuclear reactors of this sort also make other substances introduced into the radioactive. Some of the material are very useful in science and medicine for tracing complex metabolic functions, studying ecosystems, and testing materials. In these uses, only small, "safe" amounts are used. However, many of the substances are merely wastes - and highly radioactive at that. Even the "good" isotopes are eventually of no future use, and at this point they become wastes too. And, of course, when an accident occurs (Chernobyl, Three-Mile Island), radioactive materials may be released.

Nuclear wastes are particularly hazardous for several reasons. All are radioactive, and some may retain significant radioactivity for thousands of years (the radioactive materials we mine are 4 billion years old and still radioactive!). Many are toxic; plutonium, another reactor fuel and bomb material, is one of the most toxic elements known to humans. Both uranium and plutonium are heavy metals. Finally, if care is not taken is their disposal, a critical mass of radioactive materials may form in the disposal site. If this happens, excess heat and radiation will be generated; if water is present a steam explosion may also occur. An accident of this sort occurred at Chelyabinsk in Russia in 1957. An area of up to 400 square miles[3] was contaminated; up to 30 villages were evacuated as a result. It's not just the discarded final products that make up nuclear waste either; a significant portion of our nuclear waste is the mine tailings created when the uranium is mined. Disposal of nuclear wastes means that special care must be taken to prevent the materials from entering the ecosystem for a long, long time.

Other forms of "pollution" are varied. Many are not substances at all. For instance, we speak of noise pollution and thermal pollution. There is evidence that prolonged exposure to elevated noise levels can cause stress and hearing damage in humans. Many of our machines make noises much louder than natural noise sources, but this isn't always the case. Howler monkeys, spring peepers, many species of birds, etc. can make surprisingly loud noises. While machinery may not be any louder, it can often generate the noise longer than an individual organism can. Of course, when thousands of organisms congregate, the noise can be overwhelming. The seventeen-year cicada spends 17 years of its life underground, feeding on sap from tree roots. They emerge in huge numbers as adults. So many emerge that the birds cannot possibly eat them all,

[3]Cousteau Almanac

and, with a 17-year cycle, any increase in the bird population due to this feast will be long gone by the next emergence. Of course, one out of every two of these cicadas is male, and the males 'sing' by rubbing portions of their wings together. The resulting sound is very loud (you hear their cousins, the 13-year cicadas, every summer, and you know how loud they are); multiplied by the millions it is deafening. When I was in college I noticed that during an emergence of the 17-year cicadas the combined sound, inside the house, was louder than my stereo turned up to full (and it was a good stereo, too). Still, all in all, I, and most other humans, would prefer natural noises to human-created ones. It is interesting to note that OSHA regulations require warning beepers on vehicles that are louder than what that agency would normally allow workers to be exposed to.

Thermal pollution happens when we use energy to heat water or air for industrial or residential purposes. The water that cools boilers in power plants (as well as the hot air exiting the smokestacks), enters the environment at elevated temperatures. These elevated temperatures can either be a boon or a curse to the organisms in the environment. For instance, in Florida, manatees congregate in the warm water near power plants in the winter. As long as the plant doesn't have to shut down, they are fine. I know of a river in northeastern Ohio where a power plant also warms the river. The insects in the stream reach extreme sizes in the middle of the winter. I don't know what this means for them long-term. At worst, it causes them to emerge from the stream too early in the spring for their eggs to take hold. If this is the case, they are presumably replaced by others drifting in from upstream. A student at Marietta has recorded temperatures 10^{o} C warmer downstream from the Beverly power plant as opposed to upstream.

Another type of thermal pollution occurs when trees are cut down. Streams which are normally shaded may become warmed by the sunlight which reaches them after the trees are cut down. The warm water holds less oxygen, and the organisms in the stream may die. When urban areas are deforested and replaced with blacktop, temperatures in the local area (and the countryside downwind) will experience higher temperatures as well. Many U.S. official weather stations which were established in the 1800's are no longer useful because urbanization has changed the local climate enough to show a definite change. Some argue that global warming is in fact simply a relict of the elevated readings caused by urbanization at such stations.

Finally, various gases are released into the atmosphere as a result of human activities. Power plants, automobiles, and home furnaces are responsible for most of these emissions. The gases coming out of a smokestack are a mixed bag, and depend on what is being burned. Of the fuels commonly used, natural gas is the cleanest; its emissions are mainly carbon dioxide (CO_2) and water. Fuel oils of various grades come next; coal is the dirtiest. Oil and coal may contain small amounts of sulfur, which, when burned, produces SO_2, sulfur dioxide. All combustion yields some nitrous oxides (NO_2, NO_3) and

carbon monoxide (CO). Carbon dioxide is used by plants for photosynthesis; much is also taken up by the oceans. It is also a greenhouse gas implicated in raising global temperatures. Carbon dioxide, sulfur dioxide, and nitrous oxides all can combine with water in the atmosphere to produce acid precipitation.

Smog is formed when hydrocarbons (constituents of petroleum), nitrous oxides, and carbon monoxide combine with humidity to form a combination of smoke and fog — smog. Another gaseous pollutant is ozone (O_3); ozone is a lung and eye irritant, damages plants, and contributes to breakdown of rubber products. Ozone is produced by combustion and electrical generating equipment; it is also produced when sunlight strikes smog.

Other gases of concern are methane, produced by combustion and inefficient digestion (as in cows, swamps, and landfills) (methane is a greenhouse gas), chlorofluorocarbons, and halons. The latter two are responsible for damaging the ozone shield; paradoxically ozone at ground level is harmful, ozone high in the atmosphere is helpful. Finally, many of the synthetic industrial chemicals mentioned earlier can also be released in gaseous form. The Ohio River Valley is a leader in this, too (We're #1!! We're #1!! We're #1!!).

One common response to pollution is to discharge into larger rivers or to build taller smokestacks to disperse the pollutants so that they won't be as noticeable locally (local folks can see where the pollution is coming from). A friend of mine always says "the solution to pollution is dilution"; he was joking but that was before he went to work for one of the country's largest power generators. In fact, all this does is turn a local problem into a regional or even global one. In the next study guide, we will discuss problems that have become global in scope.

You should be able to:

Classify different sources of pollution.
Identify common pollutants, their sources, and the problems they cause.
Choose one of the types of pollution mentioned above, and find data on the amounts released in the United States yearly.