Public concern about groundwater degradation from point- and nonpoint-source contaminants continues to increase. If such concern is to generate responsible action, it must be informed by facts. Media coverage has not been particularly helpful in this regard: too often, the public is presented with fragmented or sensationalized information. As a result, misconceptions abound about why particular problems occur, what health risks those problems impose, and how those risks might best be reduced. This fact sheet discusses some of the more common groundwater contaminants and clarifies the potential health risks associated with them.

What Are the Common Pollutants?
Groundwater pollutants can be either organic or inorganic. Organic materials are composed primarily of carbon and hydrogen; they may also contain smaller amounts of chlorine, nitrogen, sulfur, and phosphorus. Of the 70,000 organic chemicals currently being used in the U.S., 654 have been designated hazardous by the Environmental Protection Agency (EPA). Organic chemicals currently detected in the groundwater include solvents, degreasers, petroleum components, pesticides, certain industrial by-products, and viral and bacterial pathogens.

Inorganic pollutants include materials such as nitrate, which can come from fertilizers or decayed organic materials; chlorides; and heavy metals, such as copper and lead.

Organic Pollutants and Health Problems
Organic pollutants in drinking water seldom exceed trace concentrations: a few parts per billion (ppb) or even a few parts per trillion (ppt). These levels can be likened to 1 teaspoon of liquid creamer in 1,321,000 gallons of coffee (1 ppb) or in 1,321,000,000 gallons (1 ppt). Determining the health effect of pollutants present at such low levels is extremely difficult.

Toxicity is the inherent ability to impair health. Toxic substances can cause cancer, birth defects, and other illnesses. The severity of the effect usually depends on the dose, defined as the weight of the contaminant consumed per day divided by body weight. Dosages are usually measured in milligrams per kilogram of body weight per day. Acute toxicity refers to a contaminant’s ability to cause immediately detectable health problems. Chronic toxicity refers to a contaminant’s ability to cause health problems years after a long-term exposure. Keep in mind that some contaminants that cause no detectable health problems at low doses can cause death at high doses.

Nonlethal acute toxicity is easier to diagnose and treat than chronic toxicity since the ensuing health problems are generally brief and reversible. When the exposure to the chemical ceases, so do the effects, provided that the dosage has not been too high. Examples of organic chemicals that can be acutely toxic are the polychlorinated and polybrominated biphenyls (PCBs and PBBs) — a group of chemicals used in paints, electrical transformers, insulators, and the pesticides aldicarb, paraquat, and DDT. Symptoms of acute toxicity can include diarrhea, nausea, convulsions, blurred vision, and difficulty in breathing.
Health problems from chronic toxicity are more difficult to diagnose because they often remain latent for years. Once such problems become manifest, they may be difficult or impossible to treat. These complications make chronic toxicity from organic pollutants the major concern of those investigating water quality. Depending on the chronic health problems they cause, pollutants are typically grouped in the following three classes: carcinogens, mutagens, and teratogens.

Any chemical that causes cancer, either directly or indirectly, is a carcinogen. Although carcinogenesis receives more research attention than any other chronic effect, scientists have not determined the precise relationship between carcinogens and cancer. They do know, however, that carcinogens stimulate various forms of malignant tumors.

Fewer than 30 agents have been directly linked to human cancer. In contrast, nearly 1,500 are reported as being carcinogenic in animal tests, although this number includes results from studies whose experimental designs were questionable. Only about 7,000 of the over 5 million known substances have been tested for carcinogenicity.

Among the chemicals designated as causing cancer are vinyl chloride, a component of some resins; benzene, a solvent produced in petroleum refining; and benzo(a)pyrene, which results from the incomplete combustion of coal, kerosene, and shale. Benzo(a)pyrene also results from grilling foods. Numerous other chemicals are known to produce cancer in animals; they include the pesticides ethylene dibromide (EDB), kepone, heptachlor, and dieldrin.

A chemical capable of producing an inheritable change in the genetic material is called a mutagen. We know little about the mutagenic effects of organic chemicals because most suspected mutagens have been tested only on microorganisms and animals. Chemicals found to be mutagenic on the basis of such tests include vinyl chloride, benzo(a)pyrene, bromoform, chlorodibromomethane, and the fungicides folpet and captan.

Any chemical that produces a birth defect is called a teratogen. True understanding of teratogens is very limited. Some of the chemicals shown to have teratogenic effects in animals are nicotine and the pesticides 2,4-D; 2,4,5-T; and folpet. It is important to realize, however, that studies using laboratory animals and extremely high exposure rates are not always accurate predictors of human teratogens. This fact is often overlooked and can lead to misunderstandings.

Besides the health problems discussed above, organic pollutants may also cause arteriosclerosis, heart diseases, hypertension, emphysema, bronchitis, and kidney and liver dysfunction. Some evidence also links certain organic chemicals to metabolic disorders that stimulate abnormal production of enzymes.

Inorganic Chemical Effects: Health Concerns from Nitrate

**Human Health Problems**

Humans ingest nitrates from food and water. Once nitrate enters the body of humans older than six months, it is readily absorbed from the digestive tract and excreted in the urine. Healthy human adults can consume fairly large amounts of nitrate with little harmful effect.

Infants under six months, however, are susceptible to nitrate poisoning because their undeveloped digestive tracts possess bacteria that convert nitrate into nitrite, which is toxic. When nitrite enters the bloodstream, it reacts with oxygen-carrying hemoglobin and forms a compound called methemoglobin. This compound reduces the blood’s ability to carry oxygen. As oxygen levels decrease, infants may show signs of suffocation, a condition called methemoglobinemia.

The most conspicuous symptom of methemoglobinemia is bluish skin, most noticeably around the eyes and mouth. If detected rapidly, methemoglobinemia can be successfully treated with an injection of methylene blue, which changes methemoglobin back to hemoglobin. Untreated, the condition is extremely serious: death occurs when 70 percent of the body’s hemoglobin has been converted to methemoglobin.

While rare, infant deaths from methemoglobinemia (or blue baby syndrome) have been linked to high levels of nitrate in well water. Doctors recommend using bottled water to make formula when nitrate levels exceed the drinking water standard set by the Public Health Service: 44 parts per million (ppm) of nitrate (NO₃⁻). This level is equivalent to 10 ppm of nitrate-nitrogen (NO₃⁻N). With one possible exception, no breast-fed infants have developed methemoglobinemia, probably because the mother excretes nitrate so rapidly.

**Livestock Health Problems**

Because bacteria in the rumen convert nitrate to oxygen-seeking nitrite, nitrate poisoning occurs most often in monogastric animals such as cattle and sheep. Monogastric animals such as swine and chickens have no rumen; thus they rapidly eliminate nitrate in their urine. Young monogastric animals, however, are similar to human infants in that they are highly susceptible to nitrate poisoning until their digestive systems develop. Although horses are monogastric, their large cecum acts as a rumen, converting nitrate to nitrite. Consequently, horses are more susceptible to nitrate poisoning than are other monogastric animals.

Through overfertilization or stress, many plants accumulate ni-
trate levels that can harm livestock. In water, however, nitrate rarely proves harmful. High nitrate water generally threatens animals only when it is added to high nitrate concentrations already present in ingested feed.

Symptoms of methemoglobinemia in animals include lack of coordination, labored breathing, blue coloring of mucous membranes, vomiting, and abortions. Dairy cows, however, can have reduced milk production without showing any symptoms. If you suspect that your animals may have nitrate poisoning, your veterinarian can conduct a test and, if necessary, administer an injection of methylene blue, the antidote.

Recently, a number of other health problems have been linked to high concentrations of nitrate. Some studies suggest that an increase in esophageal and stomach cancers may be related to N-nitrosamines, organic compounds formed in the mouth or digestive system by the interaction of nitrite (formed from nitrate) with compounds containing organic nitrogen (secondary amines). N-nitrosamines are potent animal carcinogens.

Most laboratories report the nitrate content as parts per million or milligrams per liter (mg/L) of either nitrate (NO₃) or nitrate-nitrogen (NO₃-N). To compare different results, you must know if they are reported as NO₃ or NO₃-N. To convert NO₃-N to NO₃, multiply by 4.4. For example, 10 ppm NO₃-N is equal to 44 ppm NO₃. Table 1 gives some general guidelines for water use.

<table>
<thead>
<tr>
<th>Nitrate (NO₃) Level (ppm)</th>
<th>Nitrate-Nitrogen (NO₃-N) Level (ppm)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-44</td>
<td>0-10</td>
<td>U.S. Public Health Service standard is 44 ppm NO₃ or 10 ppm NO₃-N. Safe for humans and livestock.</td>
</tr>
<tr>
<td>45-88</td>
<td>11-20</td>
<td>Generally safe for human adults and livestock. Do not use for human infants.</td>
</tr>
<tr>
<td>89-176</td>
<td>21-40</td>
<td>Generally acceptable for human adults and all livestock unless food or feed sources are very high in nitrates.</td>
</tr>
<tr>
<td>177-440</td>
<td>41-100</td>
<td>Dangerous for human adults and young livestock. Probably acceptable for mature livestock if feed is low in nitrates.</td>
</tr>
<tr>
<td>Over 440</td>
<td>Over 100</td>
<td>Should not be used.</td>
</tr>
</tbody>
</table>

Wells with elevated nitrate levels should be inspected for well head protection and possible on-site sources of contamination. Common sources of nitrate include septic systems, animal manure, decaying organic matter, and commercial nitrogen fertilizers.

**Table 1. Guidelines for Use of Water with Known Nitrate Content**

**Treatment**
Water contaminated with nitrate can be treated so that it meets drinking standards. Treatments are expensive, however, and include processes such as reverse osmosis, deionization, and distillation. Boiling, softening, or disinfection will not reduce the water’s nitrate content.

**Additional Reading**
For more information on nitrate, refer to *Nitrogen Management and Water Quality*, by J. V. Baird (AG-439-2). Additional information can be found in *Pollutants in Groundwater: Risk Assessment* (AG-439-8), by M. G. Cook and J. P. Zublena.
Soil Facts

Helping people put knowledge to work.

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