Groundwater Contamination

10

10.1 Introduction

Groundwater contamination follows all else in this book because you need most of what precedes it to understand the many interwoven processes involved. The fate of subsurface contamination depends on the local geology, groundwater flow patterns, pore-scale processes, and molecular-scale processes. Contamination might spread rapidly within a high-conductivity sand lens, or it might diffuse at a snail's pace through a low-conductivity clay. Some contaminants adsorb onto the surface of aquifer solids, moving very little from their source, while others migrate freely with the flowing pore water, sometimes ending up many kilometers from their source. Chemical reactions along the way can cause a contaminant to disappear, or worse, appear from apparently nowhere.

When we speak of groundwater contamination, we mean solutes dissolved in the water that can render it unfit for our use or unfit for an ecosystem that the water enters. Most natural waters contain at least some amount of dissolved substances that we think of as contaminants. Each glass of water we drink contains some lead and arsenic, for example. But in most cases, these substances are present at very low concentrations that pose no significant risk. For a contaminant to be a true problem, it must be present at a concentration that poses some significant risk to human health or an ecosystem.

The most common contaminants and their important properties are introduced first. Then the processes that affect their movement in the subsurface are discussed, followed by a few case studies. Modeling methods and field methods are then introduced briefly. The chapter ends with an overview of tactics for remediating groundwater contamination.

10.2 Contamination Sources

Sources of groundwater contamination come in a great variety of sizes and shapes. It may be a leaking underground pipeline or tank, a waste water lagoon, a septic system leaching field, a spill into a drain at a factory, or leaking barrels of waste chemicals. These examples are all relatively small and would be classified as **point sources**. On the other hand, **nonpoint sources** are larger, broadly distributed sources. Examples of nonpoint sources include polluted precipitation, pesticides applied to a cropland, and runoff from roadways and parking lots.

Sometimes contamination is introduced to the subsurface as an aqueous solution such as septic system effluent or landfill leachate. This is not always the case, though. The source of contamination can be a spilled separate liquid phase like gasoline or dry-cleaning solvent. These liquids, usually organic, are known by the acronym **NAPL**, for nonaqueous-phase liquid. NAPLs can persist in the subsurface and slowly dissolve into the water, acting as a continuous point source for years. Organic contamination and NAPLs are such a large portion of groundwater contamination problems that they are discussed separately in subsequent sections.

10.2.1 Leaking Storage Tanks

Tanks are widely used to store fuels and chemicals, and many of these have leaked over the years. Underground tanks have caused the most contamination, because they can leak slowly for a long time without being discovered. The U.S. Environmental Protection Agency estimated that by 1996 there had been 318,000 releases from underground storage tanks reported at the federal, state, and local levels in the U.S. (EPA, 1996). The most common tank sources are gas tanks at filling stations, and fuel and solvent storage tanks at industrial facilities. What leaks out of these are organic NAPLs.

Most tanks installed before the 1970s were bare steel tanks that tended to corrode. Many of these tanks and their associated piping eventually sprang leaks when corrosion went too far. Most of us have seen gas stations, temporarily closed, with gaping excavations made for removal of the old tanks and installation of the new.

Newer tank systems are most commonly made of fiberglass-reinforced plastic, coated and cathodically protected steel, or composites of these two materials. Cathodic protection greatly slows the rate of galvanic corrosion of buried steel tanks and piping. Hundreds of thousands of these new types of tanks have been in service in the U.S. for up to 30 years, with very few failures reported (EPA, 1988). New tanks sometimes have double wall layers with leak-detection devices between the walls. As of 1998, underground storage tanks in the U.S. have to meet certain requirements regarding leak detection, spill and overfill protection, and corrosion protection.

10.2.2 Septic Systems

Septic systems for subsurface disposal of human wastewater are the rule in more rural areas not served by sewers and sewage treatment systems. Most septic systems serve a single household, but some larger systems serve a cluster of homes and/or offices.

A typical septic system starts in the series of drainpipes in a home's plumbing system. These all connect and drain to one pipe that runs outside to a buried **septic tank**, where solids settle and are trapped. The tank needs to be pumped out periodically to remove accumulated solids. From the tank, wastewater flows to a **leaching field**, usually a network of porous distribution pipes set in a porous material in the unsaturated zone (Figure 10.1).

Wastewater contains dissolved organic compounds that fuel redox reactions in microbes that live in the system. Redox reactions in the tank are usually anaerobic, including fermentation, methane generation, and sulfate reduction (Wilhelm *et al.*, 1994). The water leaving the tank has high concentrations of organic compounds, CO_2, and ammonium (NH_4^+).