

involved (e.g., ^{90}Sr and ^{137}Cs) are so highly radioactive that even minute quantities can prove fatal to people if released to the surface environment.

Most studies concerning disposal of hazardous wastes—both toxic and radioactive—have concluded that underground storage is appropriate, provided safe sites can be found. In the case of high-level nuclear wastes, which can remain dangerous for tens or hundreds of thousands of years because of the long half-lives of some of the radioactive isotopes, a primary requirement is that a site will be stable over a very long time interval. Therefore, the only completely safe sites for disposing of radioactive wastes and their containers are ones that will not be affected chemically by groundwater, physically by earthquakes or other disruptive events, or accidentally by people.

The placement of hazardous wastes underground, even far underground, immediately raises concerns

about groundwater. Water is a nearly universal solvent, and the weakly acidic character of most groundwater means that any container of toxic or radioactive substances eventually is likely to corrode, so that the contents will then dissolve and be transported away from the storage site. Water is present in crustal rocks to depths of many kilometers, and in many of these rocks it is circulating at rates of 1 to 50 m/yr. Over tens or hundreds of thousands of years, even such slow rates can move dissolved substances over great distances and introduce them to more rapidly flowing parts of the hydrologic system.

There is general agreement among geologists that the ideal underground storage site for radioactive wastes should possess the following characteristics:

1. The enclosing rock should have few fractures and low permeability.
2. The enclosing rock should have no present or

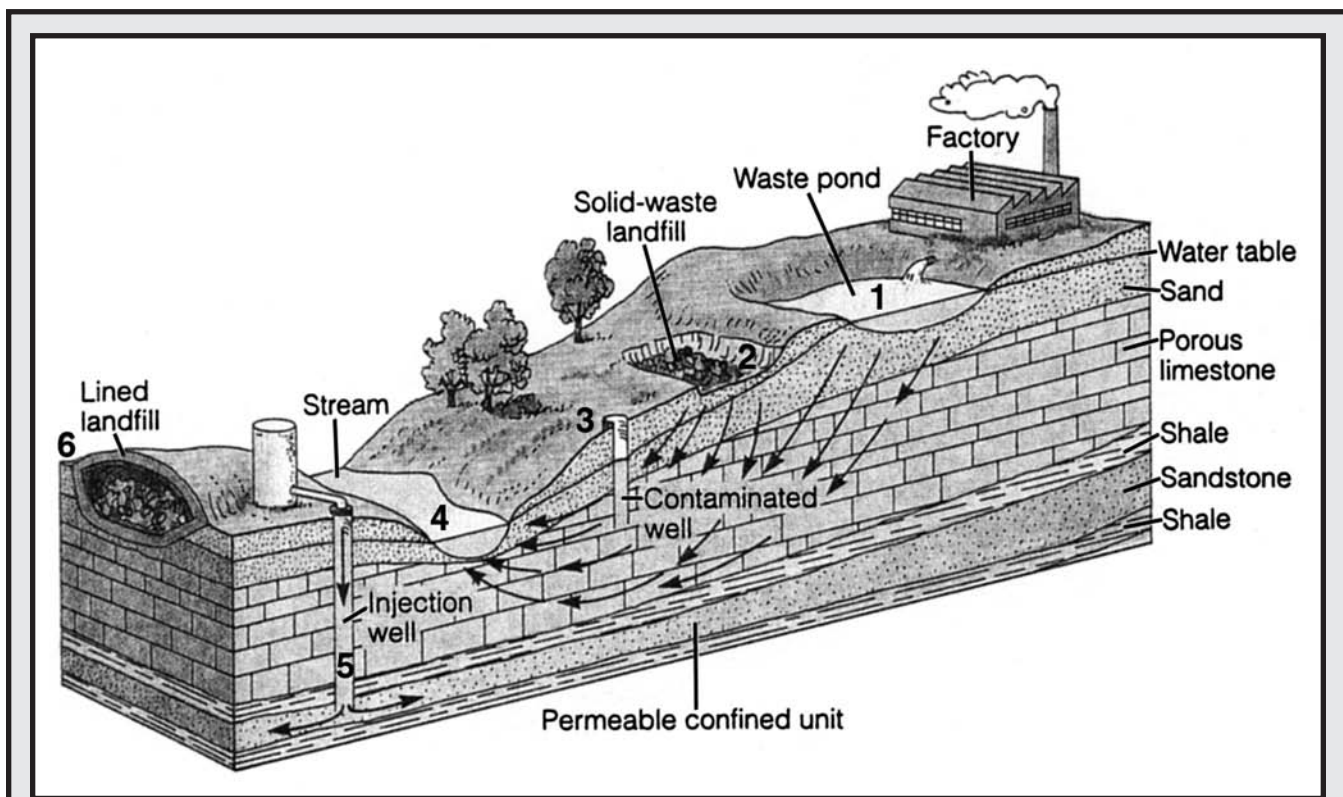


FIGURE 5-15

A groundwater system contaminated by toxic wastes. Toxic chemicals in an open waste pond (1) and an unlined landfill (2) percolate downward and contaminate an underlying aquifer. Also contaminated are a well downslope (3) and a stream (4) at the base of the hill. Safer, alternative approaches to waste management include injection into a deep confined rock unit (5) that lies well below aquifers used for water supplies, and a carefully engineered surface landfill (6) that is fully lined to prevent downward seepage of wastes. Because neither of the latter approaches is completely foolproof, constant monitoring at both sites would be required.