Groundwater Quality: Today’s Status and Tomorrow’s Research Needs

Groundwater provides drinking water for 38% of the US population – more than 130 million people. The quality of groundwater is affected by both human activities and by geochemical reactions between water and geologic materials. Human-source contaminants come from chemical spills, agriculture, pipeline and underground storage tank leaks, road salt, unlined landfills, and other inadequate disposal practices. Geologic-source contaminants that impair groundwater quality are called geogenic contaminants, and they can be mobilized into water through natural processes or through processes caused by human activities. Geogenic contaminants collectively adversely affect groundwater quality more than the combination of all contaminants introduced by human activities. Manganese, arsenic, and radium are the geogenic contaminants most commonly found at concentrations exceeding human health standards (high concentration). Each of these is found at high concentration in 5% of groundwater resources used by public drinking water supply wells in the United States. In some aquifers, 25% or more of groundwater-sourced drinking water has one or more geogenic constituent at high concentration. Nitrate is the only human-source contaminant found widespread at high concentration, and it is more prevalent in agricultural areas, with 4% of private wells and 2% of public wells found at high concentration. A nationwide survey of 109 pesticides and their degradation products in water supply wells found that pesticides or their degradation products were detected in 41% of the wells, but all concentrations were lower than human health benchmarks. Petroleum hydrocarbons have leaked from underground storage tanks at about 500,000 sites across the nation. Many of the petroleum hydrocarbon compounds biodegrade naturally requiring no added bacteria or nutrients. Monitoring of leak sites is required to verify that degradation processes are effective and decreasing the concentrations of the regulated contaminants.

There are several challenges associated with protecting and ensuring clean groundwater for future drinking water and other water needs. The biggest challenge is groundwater protection: once groundwater becomes contaminated, cleanup is slow, expensive, and often not even possible. Another challenge is the lack of understanding of the residence time of groundwater. Groundwater residence time is the total time from when water falls as rain and infiltrates the ground to when it discharges at water supply wells, streams, lakes, or the ocean. Groundwater with short residence times (i.e. less than 65 years) is more likely to have human-source contaminants or geogenic contaminants mobilized by human activity. In contrast, long residence times allow more reaction between water and aquifer minerals, which can yield higher concentrations of geogenic contaminants. Counterintuitively, while nitrogen fertilizer applications have been decreasing in recent years, concentrations of nitrate in water supply wells have stayed the same or increased. Part of the explanation is a long lag time for changes in agricultural practices to propagate through an aquifer due to long groundwater residence time. A final challenge is the lack of data and information about the concentrations and health effects of degradation products of contaminants. Many contaminants are transformed by bacteria or chemical reactions; if the original compound is transformed to a compound with the same or higher toxicity, then the transformation products must also be monitored. Thus, better methods are needed to monitor and test toxicity of transformation products.

Groundwater provides a large fraction of drinking water in the United States and around the world. Groundwater is also crucial for other water uses and ecological need. Ensuring clean, safe groundwater quality is a fascinating field with many ongoing challenges. These challenges lie at the intersection of geology, chemistry, microbiology, risk communication, public health, and public policy.