Water Quality in Selected Carbonate Aquifers of the United States, 1993-2005

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Abstract

The U.S. Geological Survey (USGS) National Water-Quality Assessment Program collected 1,048 samples from wells and springs in 12 carbonate aquifers across the United States during 1993-2005; results for all samples were available to assess the factors affecting ground-water quality. The carbonate aquifers sampled are the Basin and Range carbonate-rock aquifers, Biscayne aquifer, Castle Hayne aquifer, Edwards-Trinity aquifer system, Floridan aquifer system, Mississippian aquifers, Ordovician aquifers, Ozark Plateaus aquifer system, Piedmont and Blue Ridge carbonate-rock aquifers, Prairie du Chien of the Cambrian-Ordovician aquifer system, Silurian-Devonian aquifers/Upper Carbonate aquifer, and Valley and Ridge carbonate-rock aquifers. Samples were analyzed for major ions, radon, nutrients, 47 pesticides, and 54 volatile organic compounds (VOCs). Water quality in the 12 carbonate aquifers was highly variable. The occurrences of anthropogenic contaminants (those derived from human activities) were related to potential sources inferred by land-use characteristics but were also affected by extent of aquifer confinement, ground-water age, and oxidation-reduction state. Unconfined aquifers overlain by agricultural or urban land were the most likely to have elevated concentrations of nitrate or detections of pesticides. Unconfined aquifers overlain by urban land were the most likely to have detections of VOCs.

Differences in concentrations of dissolved oxygen and dissolved organic carbon and in ground-water age were directly related to the occurrence of anthropogenic contaminants. Other geochemical indicators, such as mineral saturation indices, were used to infer relative residence time within an aquifer, an indirect indicator of potential for anthropogenic contamination. In general, land use, oxidation-reduction status, residence time, and aquifer confinement were the most important factors affecting occurrence of anthropogenic contaminants. Although none of these factors individually accounts for all the variation in water quality among the aquifers, a combination of these factors explains most of the variation.

Concentrations of nitrate were related to contaminant sources and aquifer characteristics. Concentrations of nitrate were significantly higher in unconfined aquifers than in water from confined aquifers and aquifers with mixed confinement. Water recharged in 1953 or later had significantly higher concentrations of nitrate than water recharged prior to that date. Oxidation-reduction state was also a key factor affecting nitrate concentrations; in recently recharged waters, samples of oxic waters had significantly higher concentrations of nitrate than anoxic waters, regardless of land use in the area near the well. This implies that denitrification had occurred in the older, anoxic waters. Samples from 54 wells (5 percent) exceeded the U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) of 10 mg/L for nitrate in drinking water. The vast majority of these samples were in the Piedmont and Valley and Ridge aquifers. The median concentrations of nitrate ranged from 9 mg/L in the Piedmont to near the detection limit of 0.06 mg/L in three other aquifers. None of the water recharged prior to 1953 and only a single sample from a confined aquifer had nitrate concentrations that exceeded 10 mg/L as nitrogen.

At least 1 of the 47 pesticides analyzed was reported as present in about half samples from the 1,033 sites where pesticide data were collected. The criteria for determining pesticide detections included those values greater than or equal to the laboratory reporting level for each specific pesticide (ranging from 0.018 μg/L to as low as 0.001 μg/L) and also included values that were below the laboratory reporting

level but positively identified in the sample (estimated values). The most frequently occurring pesticide compounds were four herbicides—atrazine, simazine, metolachlor, and prometon—and deethylatrazine, a degradate of atrazine. Multiple pesticides frequently were present in a single sample of water; 34 percent of the samples had two to five pesticides in the same sample, and 4 percent of the samples had six or more pesticides. Water recharged in 1953 or later had a significantly higher number of pesticides detected than water recharged before 1953, and water from unconfined aquifers had a significantly higher number of pesticides detected than water from confined or mixed confinement aquifers. Water from sites in unconfined aquifers where land use was agricultural or urban accounted for the majority (81 percent) of detections of pesticides. Three of the aquifers had at least one pesticide detected in greater than 80 percent of the wells, and three other aquifers had at least one pesticide detected in less than 15 percent of the wells.

Concentrations of organic compounds are compared to MCLs for regulated compounds and to USGS Health-Based Screening Level (HBSL) concentrations for unregulated compounds. HBSLs are benchmark concentrations used to evaluate water-quality data in a human-health context but are not enforceable standards. No sample had a pesticide concentration that was greater than a USEPA MCL; however, two pesticides had concentrations that were greater than the HBSLs in one or more samples. Dieldrin concentrations were greater than the HBSL of 0.002 µg/L in 20 samples, 9 of which were from either domestic or public supply wells. A single sample from a domestic supply well had a diazinon concentration greater than the HBSL (1 µg/L).

One or more VOCs were detected at a concentration greater than 0.2 µg/L (the highest common laboratory reporting level) in 157 of the 799 samples in which VOCs were analyzed (20 percent). The most frequently occurring VOCs were chloroform, carbon disulfide, toluene, tetrachloroethene (PCE), and chloromethane. Detections of VOCs were more frequent in urban and mixed land-use settings than in agricultural and undeveloped settings. Three VOCs, PCE, trichloroethene (TCE) and 1,2-dichloropropane, had one sample each with a concentration greater than the USEPA MCL —the MCL is 5 µg/L for each of these VOCs.

This study has shown that water quality in carbonate aquifers has a substantial amount of variation across the aquifers studied. Common factors, such as extent of confinement or ground-water age, help explain why some carbonate aquifers have higher levels of contamination than others. A land-use practice that contributes a source of a contaminant is necessary for the presence of that contaminant in ground water; however, in some cases, transformation processes mitigate the effects of land use. These findings can be used by water-resource managers to help manage water quality in these aquifers.