Nitrate and Pesticides in Ground Water

Nitrogen is a critical plant nutrient, and most nitrogen is used and reused by plants within an ecosystem (Vitousek et al., 2002), so in undisturbed ecosystems minimal "leakage" occurs into ground water, and concentrations are very low. When nitrogen fertilizers are applied in amounts greater than can be incorporated into crops or lost to the atmosphere, however, nitrate concentrations in ground water can increase. Elevated nitrogen levels in ground water also might result from disposal of animal waste or onsite septic systems. Nitrate contamination in shallow ground water raises potential concerns for human health where untreated shallow ground water is used for domestic water supply. High nitrate concentrations in drinking water pose a risk for methemoglobinemia, a condition that interferes with oxygen transport in the blood of infants.

More than a billion pounds of pesticides (measured as pounds of active ingredient) are used in the U.S. each year to control weeds, insects, and other organisms that threaten or undermine human activities. About 80 percent of this total is used for agricultural purposes (U.S. EPA, 2011). Although pesticide use has resulted in increased crop production and other benefits, pesticide contamination of ground water poses potential risks to human health if contaminated ground water is used as a drinking water source—especially if untreated.

This indicator reports on the occurrence of nitrate and pesticides in shallow ground water in watersheds where agriculture is the primary land use, according to criteria outlined in Gilliom et al. (2007). Ground water samples were collected by the U.S. Geological Survey's (USGS's) National Water Quality Assessment (NAWQA) program from 1992 to 2003 (pesticide sampling began in 1993). NAWQA surveyed 51 major river basins and aquifer regions across the contiguous United States during this period; the agricultural watersheds sampled were within 34 of these study units. Although agriculture is more prevalent in some parts of the country than in others, the watersheds were chosen to reflect a broad range of hydrogeologic conditions and agricultural activities. Ground water samples were collected from existing household wells where possible and new observation wells otherwise, all targeted at the uppermost aquifer and avoiding locations where ground water condition could be biased by point sources (e.g., directly downgradient from a septic system). Most of the wells sampled ground water from less than 20 feet below the water table, indicating as directly as possible the influence of land use on shallow ground water quality. To the extent feasible, the wells were intended to sample recently recharged water. Data analyses were based on one sample per well. Related indicators report concentrations of nutrients and pesticides in streams that drain agricultural watersheds (see the N and P in Agricultural Streams indicator and the Pesticides in Agricultural Streams indicator).

The nitrate component of this indicator represents 1,423 wells. Results are compared with the federal drinking water standard of 10 mg/L, which is EPA's Maximum Contaminant Level (MCL) to prevent methemoglobinemia (U.S. EPA, 2006). MCLs are enforceable standards representing the highest level of a contaminant that is allowed in finished drinking water. MCLs take into account cost and best available treatment technology, but are set as close as possible to the level of the contaminant below which there is no known or expected risk to health, allowing for a margin of safety.

Data on 75 pesticides and eight pesticide degradation products were collected from 1,412 of the wells in the NAWQA study. These 83 chemicals account for approximately 78 percent of the total agricultural pesticide application in the United States by weight during the study period (Gilliom et al., 2007). Three types of U.S. EPA human health-related standards and guidelines were used to evaluate pesticide data: Maximum Contaminant Levels (MCLs) (as described above), Cancer Risk

Concentrations (CRCs), and Lifetime Health Advisories (HA-Ls). In all three cases, the standard and guideline levels are concentrations pertaining to lifetime exposure through drinking water. The CRC is a guideline for potential carcinogens associated with a specified cancer risk of 1 in 1,000,000, based on drinking water exposure over a 70-year lifetime. The HA-L is an advisory guideline for drinking water exposure over a 70-year lifetime, considering non-carcinogenic adverse health effects. Specific standards and guidelines used for this indicator are listed in Gilliom et al. (2007), and additional information on these types of benchmarks, their derivation, and their underlying assumptions is provided in Nowell and Resek (1994). For this indicator, if a chemical had multiple benchmarks, the MCL took precedence; if no MCL was available, the lower of the CRC (at 1 in 1,000,000 cancer risk) and HA-L values was selected. An exceedance was identified if the concentration of a contaminant exceeded the relevant standard or guideline (Gilliom et al., 2007).

What the Data Show

During the study period:

- Nitrate concentrations were 2 mg/L or above in 58 percent of wells sampled in areas where agriculture is the primary land use (Exhibit 1). By comparison, background nitrate levels in areas with little human influence are generally expected to be below 1 mg/L (Nolan and Hitt, 2002), which suggests that more than half of the ground water sampled has been influenced by human sources of nitrate.
- Nitrate concentrations in about 21 percent of the wells exceeded the federal drinking water standard (10 mg/L).
- About 60 percent of wells in agricultural watersheds had a least one detectable pesticide compound, and 9.5 percent had detectable levels of five or more pesticides (Exhibit 2). Roughly 1 percent of wells had pesticides present at concentrations exceeding human health benchmarks.

Limitations

Indicator Limitations

- These data only represent conditions in agricultural watersheds within 34 of the major river basins and aquifer regions sampled by the NAWQA program from 1992 to 2003. Although sample wells were chosen randomly within each agricultural watershed, the watersheds and aquifers themselves were selected through a targeted sample design. The data also are highly aggregated and should only be interpreted as an indication of national patterns; thus this indicator does not attempt to portray regional differences.
- This indicator does not provide information about trends over time, as the NAWQA program has completed only one full sampling cycle to date. Completion of the next round of sampling will allow trend analysis, using the data presented here as a baseline.
- Drinking water standards or guidelines do not exist for 43 percent (36 of 83) of the pesticides and pesticide degradation products analyzed. Current standards and guidelines also do not account for mixtures of pesticide chemicals and seasonal pulses of high concentrations. Possible pesticide effects on reproductive, nervous, and immune systems, as well as on chemically sensitive individuals, are not yet well understood.
- This indicator does not provide information on the magnitude of pesticide concentrations, only

whether they exceed or fall below benchmarks. It also does not describe the extent to which they exceed or fall below other reference points (e.g., Maximum Contaminant Level Goals [MCLGs] for drinking water).

Data Sources

Summary data for this indicator were provided by USGS's NAWQA program. Nitrate data have not yet been published and were provided directly by USGS (2007a); however, concentration data from individual sample sites are publicly available through NAWQA's online data warehouse (USGS, 2007b). Pesticide occurrence and exceedances were determined from individual site results in Appendix 6 of Gilliom et al. (2007) (http://water.usgs.gov/nawqa/pnsp/pubs/circ1291/appendix6/).

References

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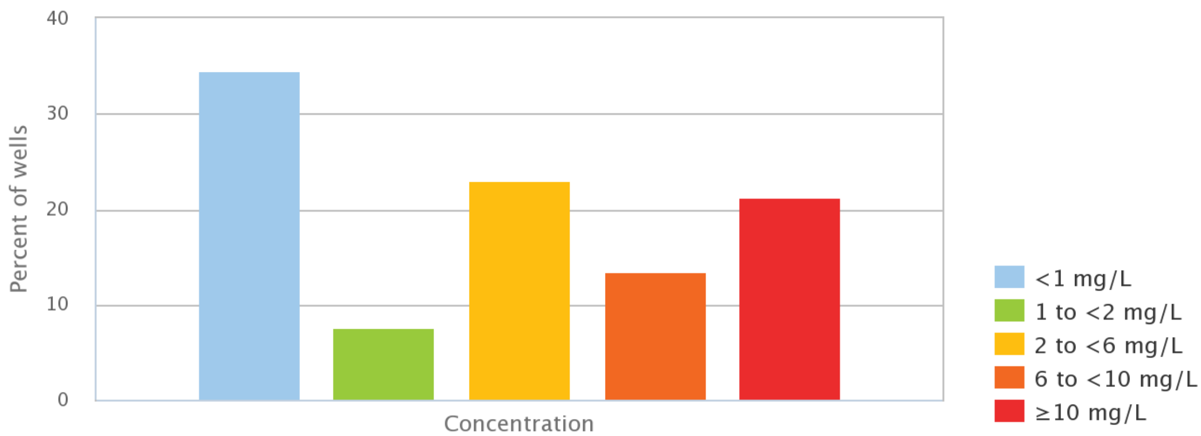
Exhibit 1. Nitrate in shallow ground water in agricultural watersheds of the contiguous U.S., 1992-2003



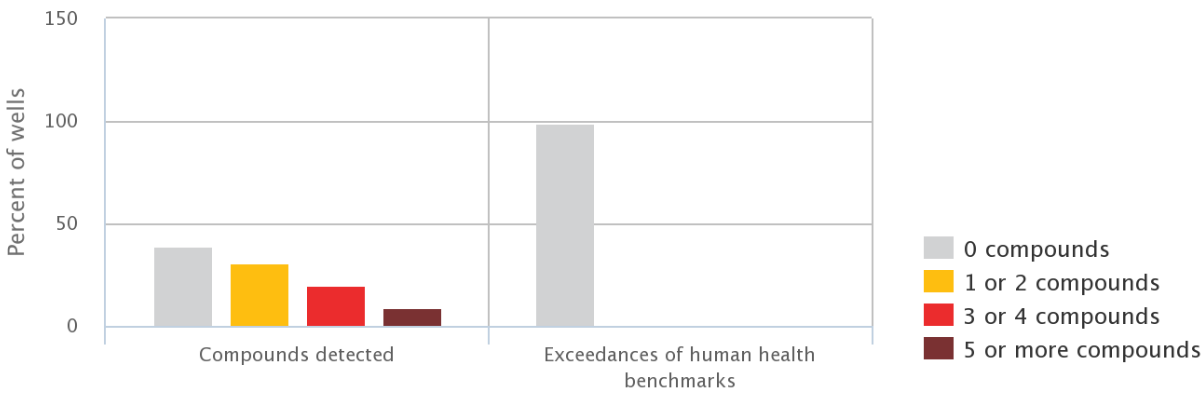
Coverage: 1,423 shallow wells in watersheds in which agriculture is the predominant land use. These watersheds are within 34 major river basins and aquifer regions studied by the USGS NAWQA Program.

EPA's drinking water standard for nitrate is a Maximum Contaminant Level (MCL) of 10 mg/L.

Trend analysis has not been conducted because these data represent one cycle of sampling. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: USGS, 2007a

Exhibit 2. Pesticides in shallow ground water in agricultural watersheds of the contiguous U.S., 1993–2003



Coverage: 1,412 shallow wells in watersheds where agriculture is the predominant land use. These watersheds are within 34 major river basins and aquifer regions studied by the USGS NAWQA program.

Samples were analyzed for 75 pesticides and eight pesticide degradation products. No wells exceeded benchmarks for more than one compound.

Trend analysis has not been conducted because these data represent one cycle of sampling. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: Gilliom et al., 2007