Pesticides in Rivers and Streams

Pesticides are chemicals or biological agents that control plant or animal pests and include herbicides, insecticides, fungicides, and rodenticides. 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 streams, rivers, lakes, reservoirs, coastal areas, and ground water can cause unintended adverse effects on aquatic life, recreation, drinking water, irrigation, and other uses. Water also is one of the primary pathways by which pesticides are transported from their application areas to other parts of the environment (Gilliom et al., 2007).

This indicator examines the presence of pesticides in rivers and streams in selected watersheds throughout the contiguous 48 states, representing a variety of land-use, climatic, and hydrologic conditions. Data come from analyses of water samples collected by the U.S. Geological Survey (USGS) between 1992 and 2011 as part of the National Water-Quality Assessment and National Stream Quality Accounting Network programs, the monitoring components of which have now been merged into a single USGS National Water Quality Network.

USGS collected data during two study periods: 1992-2001 and 2002-2011. From 1992 to 2001, suitable data for the indicator were available for 182 river and stream sites in 51 major river basins, with samples analyzed for 47 different pesticides and pesticide degradation products. From 2002 to 2011, suitable data for the indicator were available for 125 sites, with samples analyzed for 123 pesticides and degradation products. The compounds analyzed have changed over time as a result of program design changes to keep up with improved methods and the continual evolution of the pesticide marketplace (e.g., as old products are phased out and new products emerge).

This indicator tracks the percentage of time in which pesticides are detected in rivers and streams (Exhibits 1 and 2) (detection frequencies) and the percentage of sites in which pesticide concentrations exceed levels (benchmarks) that are estimated to be safe for aquatic organisms (Exhibits 3 and 4).

For detection frequencies, the percentages of time throughout the water year that pesticides were detected were calculated, weighting to account for months where more frequent sampling was done. For concentration data, exceedances were determined using chronic aquatic life benchmarks (ALBs) developed by EPA's Office of Pesticide Programs. These benchmarks are concentrations below which pesticides are not expected to harm fish, invertebrates, or other aquatic organisms, based on the best available chronic toxicity data. Altogether, one or more ALBs were available for 95 of the pesticides and degradation products analyzed. To compare pesticide concentrations with these ALB benchmarks, the data from sampling events were used to calculate moving average concentrations for each site and pesticide. The annual maximum 21-day moving average concentrations were used for comparison with chronic ALBs for invertebrates, and the maximum 60-day moving averages were compared with the chronic ALBs for fish or aquatic communities.

Exhibits 1 and 3 provide aggregate totals that cannot easily be compared over time because of differences in the list of chemicals measured during each study period. Thus, these two graphs are limited to the most recent decade of sampling (2002-2011), which provides the most current assessment available. Exhibits 2 and 4 show changes over time by comparing the first and second decades of sampling for certain common pesticides, most of which were measured during both decades. In all four exhibits, watersheds are grouped according to the dominant land use of the watershed upstream from the sampling site: agricultural, urban, or mixed-use. For more information on how these land uses are defined, see Stone et al. (2014). Most monitoring sites in agricultural and urban watersheds are on streams or small rivers, while most sites in mixed-use watersheds are on larger rivers.

What the Data Show

Detections

During the 2002-2011 study period, pesticides were detected 95 percent of the time in agricultural watersheds, 99 percent in urban watersheds, and 96 percent in mixed-use watersheds (Exhibit 1).

Exhibit 2 shows the 20 pesticides that were detected most frequently in 2002-2011. The herbicides atrazine (and its degradation product, deethylatrazine), metolachlor, and simazine were detected more than 50 percent of the time across all land uses in both decades, and prometon was detected more than 50 percent of the time in mixed-use and urban watersheds. Some pesticides were detected much less frequently in 2002-2011 than in 1992-2001. Stone et al. (2014) suggest that this decrease is likely the result of decreased use due to regulatory and market changes such as the increased use of other pesticides. Five of the 20 most frequently detected pesticide compounds in 2002-2011 were not measured in 1992-2001, in some cases because they were only recently introduced to the market. For example, fipronil is an insecticide that was registered for use in 1996 and is now present in urban streams (along with two degradation products) more than 50 percent of the time.

Exceedances

From 2002 to 2011, 90 percent of rivers and streams in urban watersheds contained at least one pesticide at a concentration higher than a chronic ALB (Exhibit 3). Rivers and streams in agricultural and mixed-use watersheds had 61 and 46 percent exceedances, respectively. Most of these rivers and streams had one or two compounds that exceeded ALBs, but a few had five or more.

Of the 13 pesticides that were found most frequently at levels higher than a chronic ALB (Exhibit 4), the herbicide metolachlor had the most exceedances in agricultural watersheds, while the insecticides malathion, diazinon, fipronil, and dichlorvos had the most exceedances in urban rivers and streams. A comparison between the two decades shows increases in exceedances for some pesticides and decreases for others.

Limitations

- These data represent monitoring sites in rivers and streams draining watersheds in major river basins sampled by USGS in the contiguous U.S. While these rivers and streams were chosen to reflect a range of land-use, climatic, and hydrologic conditions, the results are not intended to statistically represent the distribution of concentrations in all rivers and streams in the nation's watersheds. In particular, relatively undeveloped watersheds are not included in this indicator.
- This indicator provides a simple comparison of results across decades. It does not provide statistical information about trends over time, which are evaluated elsewhere (Ryberg et al., 2010, 2014; Sullivan et al., 2009).
- This indicator accounts for only 123 different types of pesticides, while more than 400 may be in use during any given year (Stone et al., 2014). For example, one notable pesticide missing from this indicator is glyphosate, the use of which has rapidly increased since 1992. Glyphosate was added to the national stream and river monitoring network in 2014. It is relatively difficult and expensive to measure, which has limited the scope of measurements.
- This indicator provides information about exceedances of chronic ALBs but not acute ALBs because sampling was not frequent enough to reliably characterize maximum annual pesticide concentrations for each monitoring site. Chronic ALBs do not account for short-lived seasonal pulses of high concentrations.
- Chronic ALBs do not account for the effect of mixtures of pesticides, which may be a concern when multiple pesticides are present at relatively high concentrations. Various combinations of pesticides can interact in different ways.
- Because of sampling frequency, concentration statistics may be over- or under-estimated. Uncertainty for longer-duration concentration statistics (i.e., 21- and 60-day) is expected to be less than for shorter-duration concentration statistics (i.e., 1-day and 4-day).
- This indicator does not examine exceedances of benchmarks for human health, as people are unlikely to regularly drink untreated river or stream water. Some drinking-water treatment processes can reduce concentrations of certain pesticides, but they can also create harmful byproducts in other cases. Thus, the levels of contaminants reported in this indicator are not necessarily representative of what people might be exposed to in drinking water.

Data Sources

Summary data for this indicator were provided by USGS based on the report by Stone et al. (2014), which provides additional analysis and interpretation. For more information about the ALBs used in Exhibits 3 and 4 of this indicator, see https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/aquatic-life-benchmarks-pesticide-registration.

References

Gilliom, R.J., J.E. Barbash, C.G. Crawford, P.A. Hamilton, J.D. Martin, N. Nakagaki, L.H. Nowell, J.C. Scott, P.E. Stackelberg, G.P. Thelin, and D.M. Wolock. 2007. Pesticides in the nation's streams and ground water, 1992-2001.

U.S. Geological Survey Circular 1291. Revised February 15, 2007. http://water.usgs.gov/nawqa/pnsp/pubs/circ1291.

Ryberg, K.R., A.V. Vecchia, R.J. Gilliom, and J.D. Martin. 2014. Pesticide trends in major rivers of the United States, 1992-2010. U.S. Geological Survey Scientific Investigations Report 2014-5135. http://pubs.er.usgs.gov/publication/sir20145135.

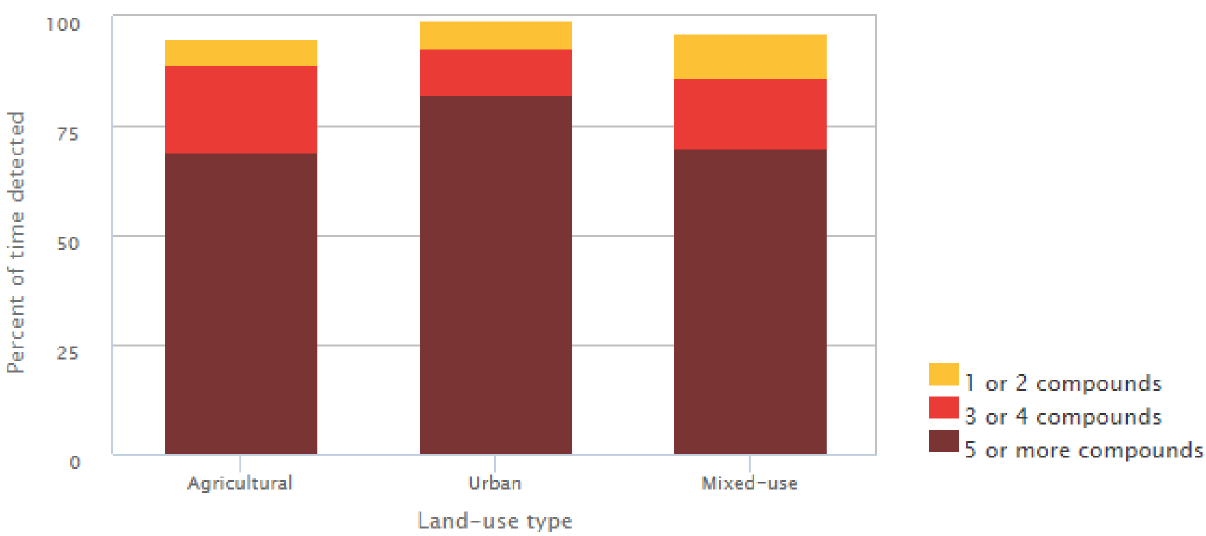
Ryberg, K.R., A.V. Vecchia, J.D. Martin, and R.J. Gilliom. 2010. Trends in pesticide concentrations in urban streams in the United States, 1992-2008. U.S. Geological Survey Scientific Investigations Report 2010-5139. http://pubs.usgs.gov/sir/2010/5139/.

Stone, W.W., R.J. Gilliom, and J.D. Martin. 2014. An overview comparing results from two decades of monitoring for pesticides in the nation's streams and rivers, 1992-2001 and 2002-2011. U.S. Geological Survey Scientific Investigations Report 2014-5154. http://dx.doi.org/10.3133/sir20145154.

Sullivan, D.J., A.V. Vecchia, D.L. Lorenz, R.J. Gilliom, and J.D. Martin. 2009. Trends in pesticide concentrations in corn-belt streams, 1996----2006. U.S. Geological Survey Scientific Investigations Report 2009-5132. http://pubs.usgs.gov/sir/2009/5132/.

U.S. EPA (United States Environmental Protection Agency). 2011. Pesticides industry sales and usage: 2006 and 2007 market estimates. February 2011. http://www.epa.gov/sites/production/files/2015-10/documents/market_estimates2007.pdf (PDF) (41 pp, 507K).

Exhibit 1. Pesticides detected in rivers and streams of the contiguous U.S., by land-use type, 2002-2011



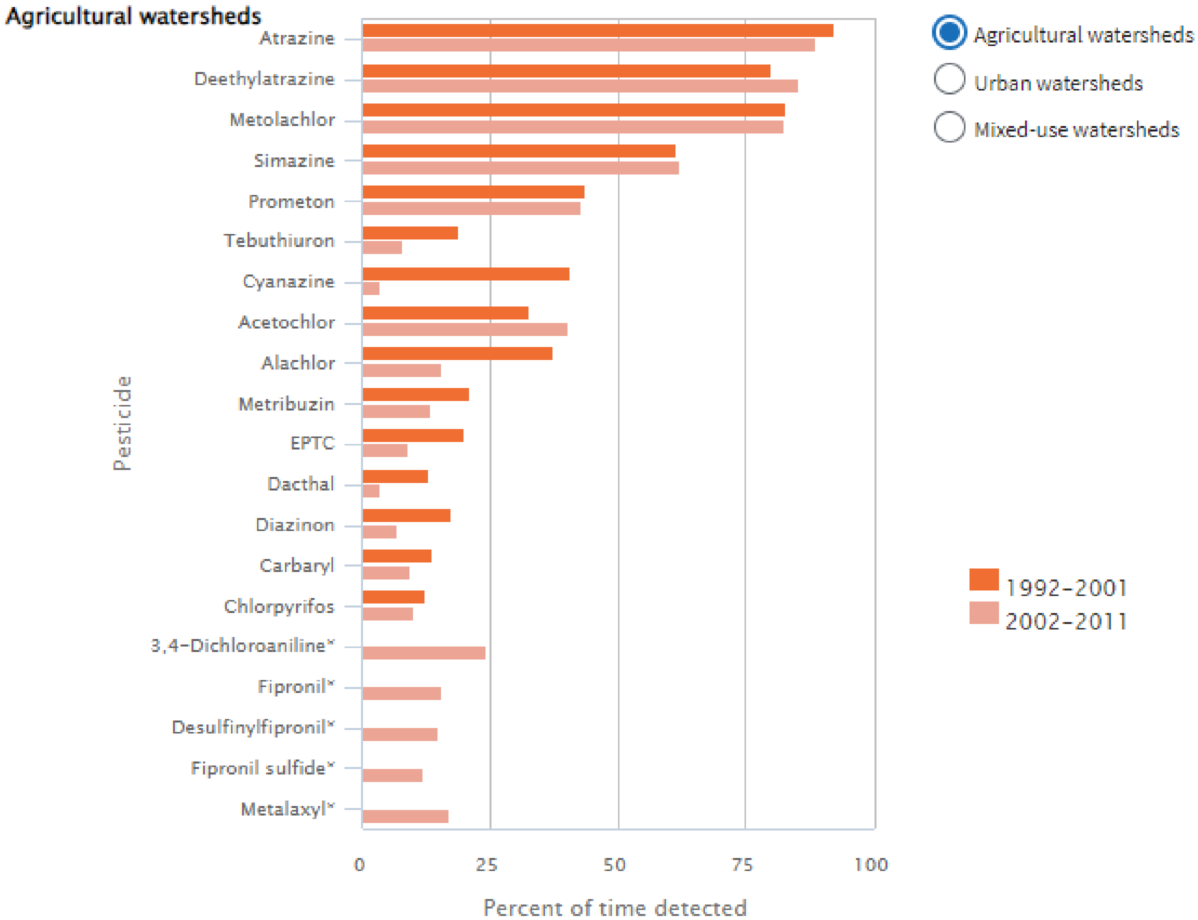
Coverage: 125 river and stream sites in selected watersheds throughout the contiguous 48 states, representing a variety of land-use, climatic, and hydrologic conditions. These data include 36 agricultural, 30 urban, and 59 mixed-use sites.

Parent compounds and degradation products are counted separately. Thus, a sample with detections of both atrazine and its degradate deethylatrazine would be considered to have two detected compounds.

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: Stone et al., 2014

Exhibit 2. Changes in pesticides detected in rivers and streams of the contiguous U.S., by land-use type, 1992–2011



Coverage: River and stream sites in selected watersheds throughout the contiguous 48 states, representing a variety of land-use, climatic, and hydrologic conditions. There are 59 agricultural sites for 1992–2001 and 36 for 2002–2011.

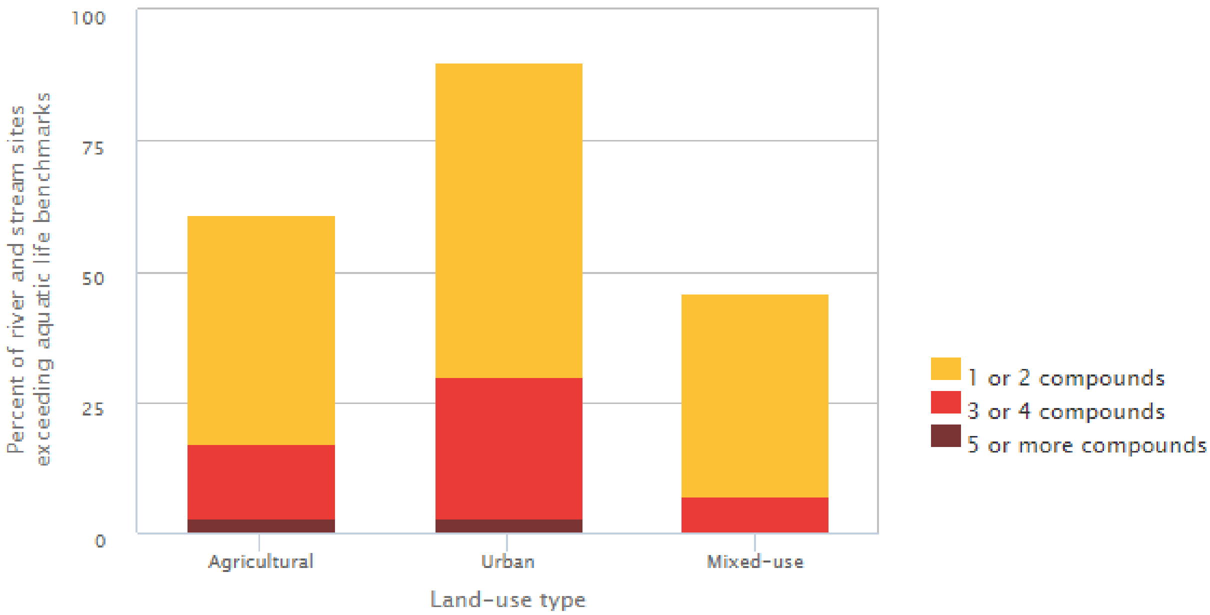
Pesticides marked with a * have no data from 1992 to 2001 because they were not included in sufficient sample analysis during that timeframe.

Information on the statistical significance of changes over time is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: Stone et al., 2014

Visit https://www.epa.gov/roe to see the full exhibit.

Exhibit 3. Pesticides exceeding aquatic life benchmarks in rivers and streams of the contiguous U.S., by land-use type, 2002-2011

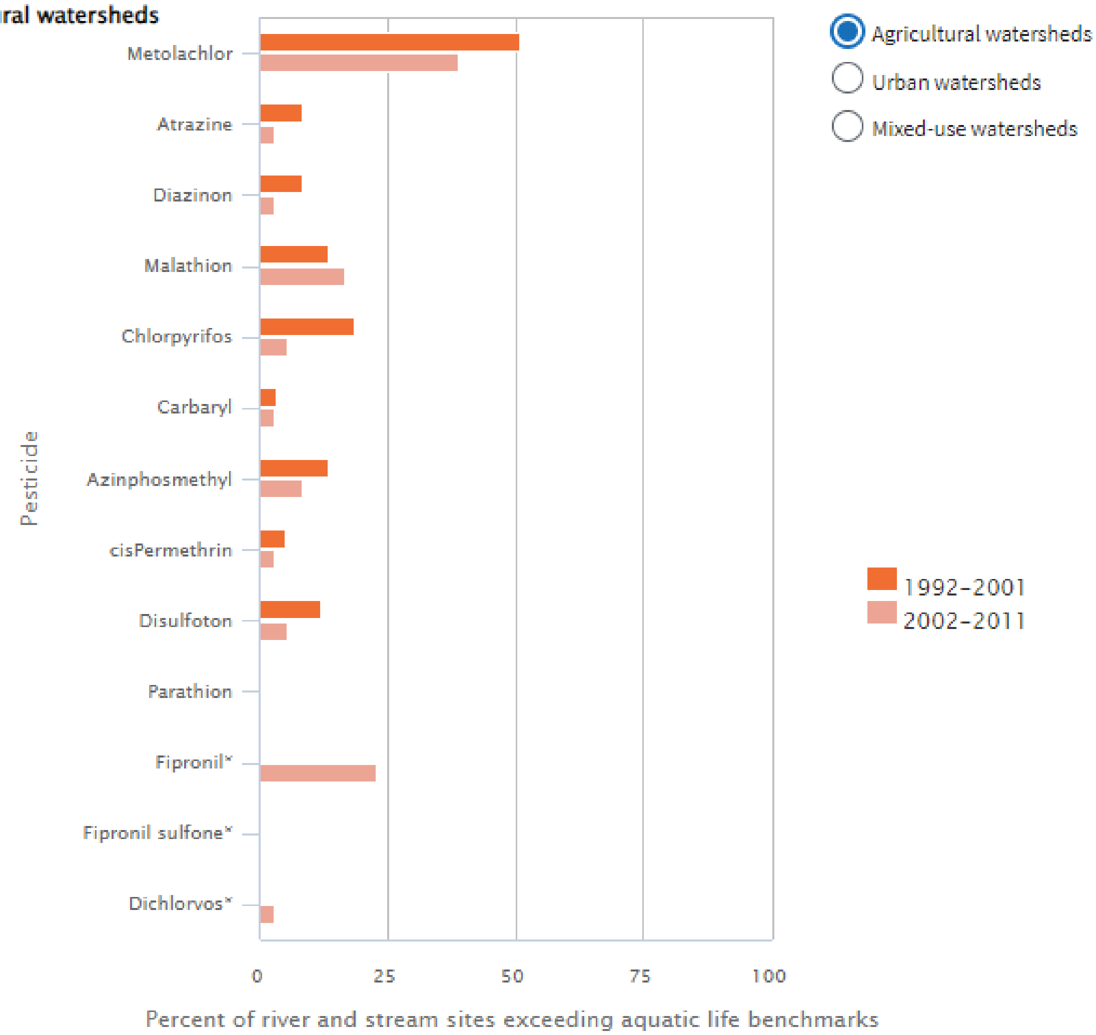


Coverage: 125 river and stream sites in selected watersheds throughout the contiguous 48 states, representing a variety of land-use, climatic, and hydrologic conditions. These data include 36 agricultural, 30 urban, and 59 mixed-use sites.

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: Stone et al., 2014

Exhibit 4. Changes in pesticides exceeding aquatic life benchmarks in rivers and streams of the contiguous U.S., by land-use type, 1992-2011



Coverage: River and stream sites in selected watersheds throughout the contiguous 48 states, representing a variety of land-use, climatic, and hydrologic conditions. There are 59 agricultural sites for 1992-2001 and 36 for 2002-2011.

Pesticides marked with a * have no data from 1992 to 2001 because they were not included in sufficient sample analysis during that timeframe.

Information on the statistical significance of changes over time is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: Stone et al., 2014

Visit https://www.epa.gov/roe to see the full exhibit.