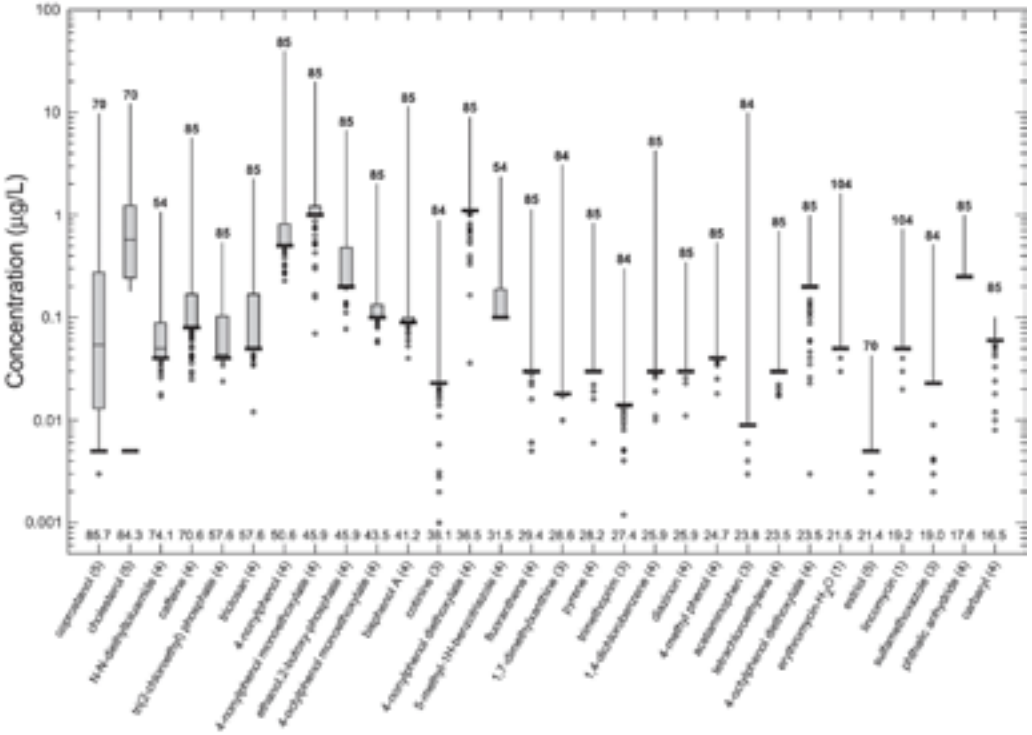
Pharmaceuticals and Other Wastewater Products in Our Waters – a New Can of Worms?

Betsy Woodhouse, Ph.D. *– Publisher, Southwest Hydrology, SAHRA*

In 1999 and 2000, the U.S. Geological Survey (USGS) tested 139 streams in 30 states for the occurrence of contaminants that may be derived from human and animal use of pharmaceuticals and other chemicals, and passed into our wastewater. The sampling locations were biased toward stream reaches likely to contain organic wastewater components, such as those downstream of intensely urbanized areas or stockyards. Each site was sampled once. Samples were analyzed for 95 wastewater-related pharmaceuticals, hormones, and other organic wastewater contaminants (OWCs) using new methods developed by the USGS that are capable of detecting concentrations in the nanogram per liter (part per trillion) range. There are no drinking-water standards or health advisories for 81 of the compounds, but many are known endocrine disruptors.



Measured concentrations for the 30 most frequently detected organic wastewater compounds. Box plots show concentration distribution truncated at the reporting level. Estimated values below reporting level are shown. Number of observations is given at top of each plot; detection frequency is at bottom of each plot. The USGS analytical method number is provided in parentheses at the end of each compound name. Reprinted with permission from Kolpin and others, 2002. Copyright 2002 American Chemical Society.

The results of this national investigation were published in 2002 (Kolpin and others), inciting strong interest by wastewater treatment plant operators, water suppliers, regulators, toxicologists, chemical analysts, and many others. Results of the baseline survey warrant particular attention in the semi-arid Southwest, where effluent-dominated streams are common and the compounds are less likely to be diluted by other surface-water sources. Seven streams in the Southwest were sampled in the USGS study; findings for those sites were discussed in the November/December 2002 issue of *Southwest Hydrology*.

Widespread Detection at Low Concentrations

The USGS study detected one or more of the compounds in 80 percent of the samples; half of the streams contained seven or more compounds, and one sample contained 38 compounds.

Eighty-two of the 95 compounds were detected at least once nationwide. The most frequently detected compounds included steroids (including cholesterol), nonprescription drugs (such as caffeine, nicotine metabolites, and pain relievers), and DEET, the active ingredient in many insect repellents. Detergents, steroids, and plasticizers generally were detected at the highest concentrations; however, most were less than 1 part per billion (ppb). Antibiotics were detected in more than 50 percent of the samples. The tables above and on the opposite page summarize results for different chemical groups. Note that these streams are likely to have contained these compounds for some time; but only recently have we been able to detect them at the minute concentrations at which they occur.

Results Raise New Questions

While answering basic questions about which compounds are present in U.S. streams and at what concentrations, the results of the USGS investigation raise many new questions, among them:

- What is the persistence and fate of these chemicals in the environment? What are their travel times, decay rates, byproducts, and reactive products? What happens to them in the vadose and saturated zones?
- Is it possible to evaluate the toxicity to ecosystems and humans of this "OWC cocktail"? How will standards be established for maximum allowable concentrations in wastewater, surface water, and drinking water?

Tucson USGS employee Dave Anning uses a Teflon conesplitter to divide samples among 10 bottles to go to different labs for analysis.

- To what extent do existing water treatment technologies remove these compounds? To what levels should the concentrations be reduced?
- Do we have the capability and methodologies to analyze for these compounds on a widespread basis? What detection limits will be required of the analytical methods?

What Next?

To answer these questions, researchers are approaching the issues from many different angles. The USGS recently completed a baseline survey of groundwater in areas susceptible to wastewater contamination and an additional survey of untreated drinking water sources. The groundwater investigation sampled 47 locations in 18 states downgradient of landfills, unsewered residential developments, animal feedlots, or other potentially contaminating sources. The samples were analyzed for 83 OWCs. Untreated drinking water samples were obtained from 25 groundwater and 49 surface-water sources across 25 states and Puerto Rico, and analyzed for 124 OWCs. Complete results are targeted for publication in late 2004. The USGS Toxic Substances Hydrology Program is conducting many additional investigations on the fate and persistence of OWCs in the environment and their effects on ecosystems.

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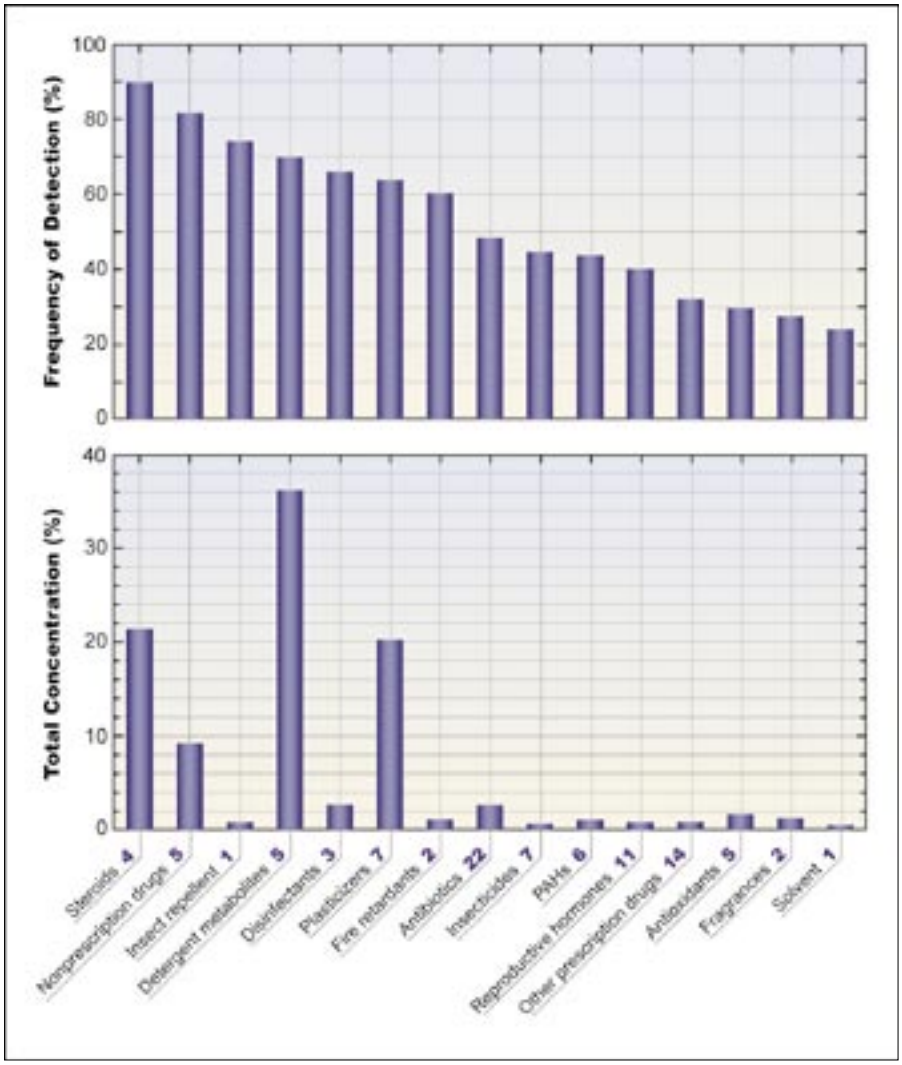

Frequency of detection of organic wastewater contaminants (top) and percent of total measured concentration of organic wastewater compounds (bottom) by general use category. Number of compounds tested in each category is shown after name. Reprinted with permission from Kolpin and others (2002). Copyright 2002 American Chemical Society.

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Numerous municipalities are attempting to analyze their own wastewater, recharge water, groundwater, and drinking water for the compounds identified in the 2002 USGS study. However, smaller agencies without high-tech laboratories have difficulty finding laboratories able to perform the analyses, and the costs are high and waiting times long. Standard methods for analyzing many of the compounds remain to be developed.

Some large municipalities and other research groups are testing methods to remove the compounds from wastewater. For example, the Orange County Water District is classifying compounds according to their chemical structure and developing models to predict the removal of classes of compounds by reverse osmosis.

In studying the fate of pharmaceuticals during groundwater recharge, Drewes and others (2003) found that caffeine, many anti-inflammatory drugs, and blood lipid regulators were reduced to nondetectable concentrations in less than six months during groundwater recharge of treated wastewater at two Arizona sites. However, some anti-epileptic medications persisted in both saturated and unsaturated zones during travel times of up to eight years.

(above) USGS employees Jennifer Menefee and Frank Schaffner collect sample from Tucson's Ina Road wastewater treatment plant flume; (top right) Menefee and Bob Hemauer sample effluent in the Santa Cruz River at Trico Road near Tucson. (photos courtesy of USGS)

University of Arizona researchers have developed several different in-vitro bioassays to test for estrogenic activity in water. The tests are being used to evaluate the presence of pharmaceuticals and personal care products (PPCPs) in reclaimed water and stormwater runoff. Preliminary results comparing estrogenic activity in groundwater sampled near locations of wastewater recharge suggest that the passage of wastewater through a managed infiltration system, such as a constructed wetland, may improve water quality over unmanaged, incidental recharge of wastewater through a streambed.

A Goal for the Future: The Green Pharmacy

Christian Daughton, of the U.S. Environmental Protection Agency's National Exposure Research Laboratory in Las Vegas, has proposed an environmental stewardship program for PPCPs called the Green Pharmacy (Daughton, 2003a, 2003b). His plan calls for "cradle-to-cradle stewardship" involving the medical community, environmental scientists, and consumers in a comprehensive effort to minimize the environmental release or disposition of PPCPs.

Daughton's Green Pharmacy approach covers the design, delivery, prescription, dispensation, packaging, advertising, marketing, database development, disposal, and recycling of PPCPs. For example, drugs could be designed to biodegrade more rapidly, and to break down to innocuous end products. Patent extensions could be offered as incentives to companies that develop stewardship programs for each drug. Drug take-back programs could be developed, as in Canada and Australia, so drugs can be recycled and kept out of the environment. Expiration dates and dosing directions could be revised.

Regulation is another approach for minimizing the introduction of PPCPs into the environment; however, Daughton suggests that stewardship may ultimately accomplish more. Standards may be established for concentrations of specific compounds in the environment, but pharmaceuticals in use are continually changing, with old drugs being retired and new ones introduced. The task of determining acceptable concentrations of such a moving target would be formidable. Thus, rather than trying to determine what concentrations in the environment are acceptable and treating to that level, adopting a production-through-recycling philosophy of minimizing the introduction of all PPCPs to the environment makes better sense.

Sources for Additional Information

USGS Toxic Substances Hydrology Program, National Reconnaissance of Pharmaceuticals, Hormones and Other Organic Wastewater Contaminants in U.S. Streams: toxics.usgs.gov/highlights/impact.html

PPCPs as Environmental Pollutants (EPA site): www.epa.gov/nerlesd1/chemistry/pharma/index.htm

The Green Pharmacy: www.epa.gov/nerlesd1/chemistry/ppcp/greenpharmacy.htm

References

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Drewes, J.E., T. Heberer, T. Rauch, and K. Reddersen, 2003. Fate of pharmaceuticals during ground water recharge. Ground Water Monitoring & Remediation, 23(3): 64-72.

Kolpin, D.W., E.T. Furlong, M.T. Meyer, E.M. Thurman, S.D. Zaugg, L.B. Barber, and H.T. Buxton, 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. Streams, 1999-2000: A national reconnaissance. Environmental Science and Technology, 36(6): 1202-1211. Online at toxics.usgs.gov/highlights/impact.html