Water Technology

Drugs in the water

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Feature
How should you respond to customers' concerns?

by: David M. Bauman

The Associated Press (AP), after a five-month investigation, recently published its findings1 about the prevalence of pharmaceuticals (sidebar) in drinking water and drinking water sources. Sources for the investigation included scientific reports, federal databases, environmental study sites, treatment plants and more than 230 interviews.

The news agency's reporters also surveyed the nation's 50 largest cities and a dozen other major water providers, as well as smaller community water providers in all 50 states.

Before this year, the pharmaceuticals-in-drinking-water issue was only dimly in the public consciousness. Water and wastewater treatment plants in the United States typically do not remove pharmaceuticals, and the AP further points out that even now the levels being found are usually measured in parts per trillion, below the prescription dosage. Also, The US Environmental Protection Agency (EPA) does not have pharmaceuticals listed in its drinking water standards. So until now there has been little cause for municipal water agencies to be testing for them or to be aware if they are present.

But as a result of the AP's report (disseminated by its hundreds of subscriber news organization), consumers and public officials now have plenty of questions (last month, a Senate subcommittee held hearings on the matter). To help water treatment professionals be in a position to provide some answers, Water Technology® recently took its own look at the issue.

How they enter water
Many people flush pharmaceuticals, over-the-counter medicines, livestock and pet medicines, and personal care products down the toilet or toss them into the trashcan. Other contributors are pharmaceutical industries, hospitals and other healthcare facilities.

Since about 90 percent of oral drugs can pass though our bodies unchanged, many of these drugs enter the environment through human and livestock waste. These eventually make their way into private and municipal water supplies.

With the increasing popularity of groundwater recharge (adding water to an area where it will supplement natural runoff or rainwater) in the United States, scientists2 have concurred that groundwater may become contaminated with pharmaceuticals. One of them adds that the risk that pharmaceuticals will be found in groundwater is "relatively high" for locations where surface water intrudes into groundwater.

Molecular sizes and membranes
Because 2 percent or less of all water entering a household is ingested by humans3, point-of-use/point-of-entry (POU/POE) water treatment for trace occurrences of substances like pharmaceuticals would seem to be a very cost-effective approach.

The Colorado School of Mines, a public engineering research university in Golden, CO, studied the effectiveness of nanofiltration (NF) and reverse osmosis (RO), among other technologies, to remove certain pharmaceuticals from wastewater. Full-scale municipal facilities were used in the study.

None of the investigated drugs were detected in tertiary treated effluents after NF or RO. From this we can presume that at least some of the pharmaceuticals can be removed by existing membrane technology.

An RO membrane removes species as small as about 0.000099 micron (μm). A look at the sizes of a few random (non-pharmaceutical) organic molecules4, ranging from 0.00086 μm to 0.0015 μm, suggests that RO technology would generally be fine enough to remove them. But are all pharmaceuticals in this size range?

UF and ozone

Given the thousands of drugs and personal care items on the market, it's possible that some species would pass through the smallest-pore membranes.

On the other extreme, many drugs incorporate larger reacting molecules like enzymes. Most enzymes are in the range of ultrafiltration (UF) membranes, 0.002 μm to 0.02 μm5. Proteins can have both positive and negative charges6, so it's possible they would be attracted to ion exchange resins. And adsorbing anion resins might have a role in removing the larger organic molecules.

In a German study7, granular activated carbon (GAC) and ozonation used in a lab and in a water treatment plant, often in series, were very effective at removing carbamazepine, diclofenac and bezafibrate. The lab also showed that 3.0 milligrams per liter (mg/L) of ozone cut primidone levels by nearly 90 percent. Although neither GAC nor ozonation at any concentration was fully successful with clofibric acid separately, the two in combination cut levels of the drug to below the limits of detection during plant testing.

Activated carbon, ozone, UV

GAC is effective because carbon can pick up a broad category of compounds, and many pharmaceuticals have components like benzene rings or amine groups that enhance their ability to be taken up by the activated carbon7.

Shane Snyder, research and development project manager for the Southern Nevada Water Authority, testified in mid-April to a US Senate subcommittee about the pharmaceuticals issue on behalf of the American Water Works Association (AWWA), the water utility trade group. In an interview with *Water Technology®*, he said the powdered form of activated carbon can be even more effective if used properly.

He said ozone's effectiveness is tied to its ability to chemically attack the pharmaceutical molecules. For example, it can oxidize different kinds of functional aromatic bonds (forces binding certain carbon-based atomic structures within molecules) in pharmaceuticals.

In the German study, Ternes states that his research has shown ozone capable of easily oxidizing 90 percent of 51 different pharmaceuticals. It is particularly effective with compounds with amine groups and phenolic hydroxyl groups.

Advanced oxidation processes using a combination of ozone and UV or ozone and hydrogen peroxide8 have likewise shown promise in removing some of these contaminants. The Water Quality Association (WQA) has also included distillation products on its list of promising pharmaceutical-removal technologies.

Solutions, and cautions

Drugs contain organic chemicals, volatile organic chemicals, inorganic chemicals, plant products, proteins and amino acids, and more. There are drugs that are hydrophobic (water-repelling) and hydrophilic (water-attracting). How will hydrophobic drugs react in a water environment? Given this, it's possible that some pharmaceuticals will require one type of treatment and some another.

Looking at bottled water and home drinking water systems, the AP said that some bottlers simply repackage tap water and that neither bottlers nor manufacturers of treatment equipment test for pharmaceuticals. Strictly speaking, this is true, but AP should have also noted that there are bottlers that use, among others, RO, NF and GAC, three of the promising treatments. And it's likely that the POE/POU industry has the necessary technology to remove pharmaceuticals with other products. Product testing will be required to prove it.

Given the very large number of pharmaceuticals and the wide variety of chemical compounds found in them, it's clear that one particular treatment is probably not going to remove them all. Most studies have looked at only two to six drugs, so it would be difficult to promote any single POU/POE technology or product as a panacea for pharmaceutical removal.

Studies on this subject to date include many qualifiers. In the example above, for instance, both activated carbon and ozonation failed to remove one drug, but they were successful when used together. Testing so far has included RO, NF, GAC, and ozonation, but testing will also be needed for UF, microfiltration (MF), distillation, sub-micron cartridge filters, and carbon blocks.

A favored approach

Removal of pharmaceuticals today could be likened to the issue of removal of volatile organic chemicals (VOCs) 20 years ago. At that time, very little was known about VOC removal and there was no product testing. Now we know that we can be relatively successful at removing VOCs, but some treatments work better on some VOCs than on others.

POU/POE will likely be a favored treatment approach for pharmaceuticals due to the economy of treating only the water used for drinking as opposed to entire municipal supplies.

There is now little reason for panic due to the low concentrations of pharmaceuticals found. However, future research may well show the cumulative effects of drugs in the body; it will certainly show more about the relative health risks and prevalences of specific ones. When that happens, there will undoubtedly be tested products at the ready, at least for the most prevalent and potentially harmful drugs.

Notes:

1. J. Donn, M. Mendoza and J.Pritchard, "AP Probe Finds Drugs in Drinking Water," Associated Press (various outlets), March 9, 2008.
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3. "Pharmaceuticals in Water," Water Quality Association (WQA) press release, March 11, 2008.
4. British Broadcasting Corp. (BBC), "Size Matters: How Big are Molecules?," BBC educational Web site: **www.bbc.co.uk/dna/h2g2/A791246**, July 10, 2002.
5. Haruo Takahashi, "Enzyme Stabilization in Mesoporous Materials," Group I, R&D Review of Toyota CRDL, Vol. 35, No. 4 (2000.12), copyright 2000, Toyota Central R&D Labs, Inc.
6. The Biology Project, Department of Biochemistry and Molecular Biophysics, The University of Arizona (www.biology.arizona.edu), October 2004.
7. T.A. Ternes, et al., "Removal of Pharmaceuticals During Drinking Water Treatment," ESWE-Institute for Water Research and Water Technology, Wiesbaden, Germany, DVGW-Technologiezentrum Wasser, Karlsruher Strasse 84, D-76139 Karlsruhe, Germany, and Institute for Water Research GmbH, Zum Kellerbach 46, D-58239 Schwerte, Germany, June 11, 2002
8. M. M. Huber, S. Canonica, G.Y. Park, and U. von Gunten, "Oxidation of Pharmaceuticals during Ozonation and Advanced Oxidation Processes," copyright 2003, American Chemical Society.

David M. Bauman, CWS-VI, CI, CCO, is technical editor of Water Technology®, *author of the magazine's monthly "Professor POU/ POE" technical advice column, and a water treatment consultant in Manitowoc, WI. He can be reached by e-mail at:* **dp-bauman@sbcglobal.net**.