science for a changing world

Wastewater Chemicals in Colorado's Streams and Ground Water

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What are wastewater chemicals?

Chemicals that we use every day in homes, industry, and agriculture — including detergents, disinfectants, fragrances, fire retardants, nonprescription drugs, and pesticides (fig. 1) — can enter Colorado's streams and ground water with wastewater. These wastewater chemicals can be released to the environment through discharges from industrial facilities, animal feed lots, wastewater treatment plants (WWTPs), individual septic disposal systems (ISDSs), or through runoff from land applications in agricultural and urban areas.

The human health and environmental effects of wastewater chemicals are not well understood, and standards to protect human health or aquatic life have not been established for most of these chemicals. Some chemicals, however, such as the detergent degradation product nonylphenol and the fragrances AHTN and HHCB, have been shown to disrupt reproduction and growth in fish by affecting endocrine systems (Thorpe and others, 2001; Schreurs and others, 2004). Other chemicals, such as the antimicrobial disinfectant triclosan found in many liquid soaps, dishwasher powders, and plastics, are suspected of increasing the antibiotic resistance of bacteria in the environment (McMurry and others, 1998) or of reducing algae diversity in streams (Wilson and others, 2003). Little is known about the effects of many other individual chemicals or about the potential additive or interactive effects of mixtures of these chemicals.

Until recently, there have been few analytical methods capable of detecting these chemicals at the low concentrations found in the environment (Kolpin and others, 2002). The U.S. Geological Survey (USGS) National Water-Quality Laboratory in Denver, Colo., has developed a new analytical method to measure concentrations of 62 wastewater chemicals in water (Zaugg and others, 2002). Methods were developed to measure these particular chemicals because they are expected to enter the environment through common wastewater pathways, are used in significant quantities, may have human or environmental health implications, and can be accurately measured in environmental samples by using available technologies (Kolpin and others, 2002).

Photograph by Jon Nania, U.S. Geological Survey

Figure 1. Chemicals that we use every day in homes, industry, and agriculture can enter Colorado's streams and ground water with wastewater.

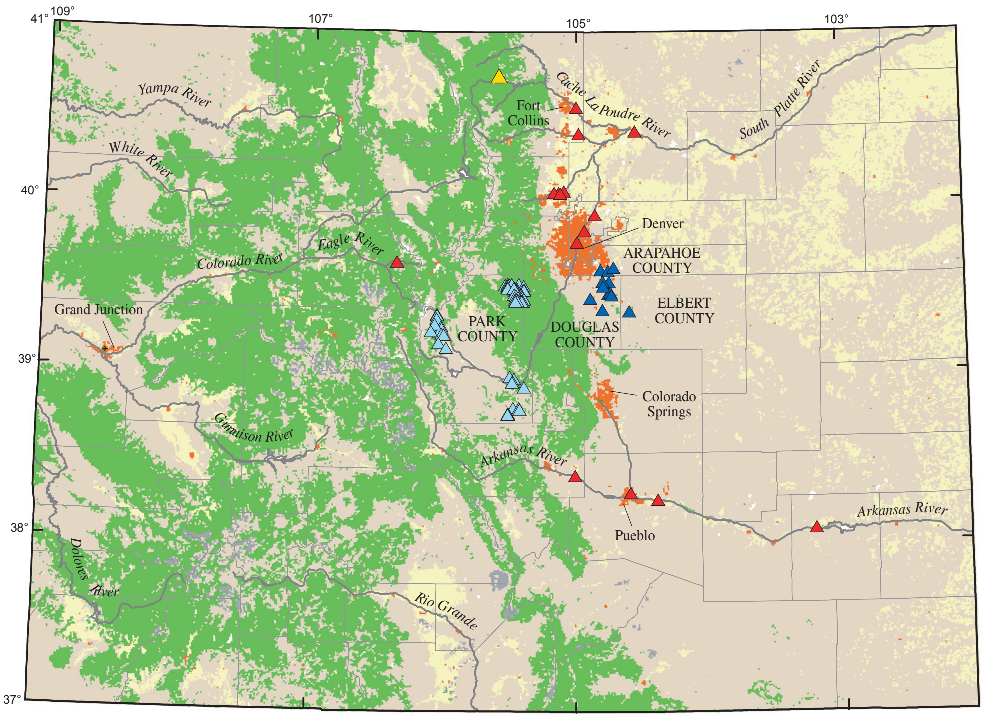

Figure 2. The U.S. Geological Survey has conducted a small number of studies in Colorado examining the occurrence of wastewater chemicals in streams in urban and forested areas and in ground water from domestic and municipal wells.

What do we know about the occurrence of these chemicals in Colorado?

The USGS, through its National Water-Quality Assessment and Toxic Substances Hydrology programs and in cooperation with local agencies, has conducted a small number of studies of the occurrence of wastewater chemicals in streams and ground water in Colorado (fig. 2). This report describes results from four types of sites — streams in urban areas, streams in forested areas, ground water from domestic wells, and ground water from municipal wells — sampled between August 2001 and September 2003. Results for individual chemicals are grouped into 12 major general-use categories, such as fragrances and disinfectants (fig. 3), as has been done previously (Kolpin and others, 2002). For chemicals having multiple uses or sources, a primary use of the chemical was chosen for categorization purposes. Because sampling was done during separate studies, different numbers of samples were collected at each type of site. Differences in the number of chemicals detected among site types may be due to differences in the number of samples collected, as well as to differences between site-type characteristics. The total number of samples and the frequency of detection (in percent) are shown along the top of each plot to allow easier comparison between site types. All data shown in figure 3 are available at *http://waterdata.usgs.gov/co/nwis/qw/*.

Between August 2001 and September 2003, 23 samples were collected at 15 sites on urban streams: 10 were in the South Platte River basin, 4 were in the Arkansas River basin, and 1 was in the Upper Colorado River basin. The areas draining to these sites ranged from moderately to highly urbanized. Some sites were located immediately downstream from a single large WWTP discharge site, whereas others were located farther downstream from one or more WWTP discharge sites of various sizes. All may have been affected at some point in their upstream drainage area by ISDS leachate or agriculture.

Between October 2002 and September 2003, 17 samples were collected at 1 forested stream site. The site was located on the Cache la Poudre River, upstream from its confluence with the North Fork of the Cache la Poudre River. Most of the drainage area upstream from the site is in either the Roosevelt-Arapahoe National Forest or Rocky Mountain National Park. The river is used for fishing, whitewater rafting, and kayaking, and there are campgrounds and isolated private homes with ISDSs along the river. There is very little urban development and no WWTP discharge site upstream from the study site.

One sample was collected from each of 75 domestic wells between September 2001 and August 2003 (Brendle, 2004; Ortiz, 2004a and b). The wells were completed in the fractured-rock and sedimentary aquifers in Park County, Colo., about 30 miles southwest of Denver. Increasing development in Park County has led to an increase in the number of ISDSs in the region. Depending on the permeability of the aquifer, the distance from the ISDS to the well, and the rate of water flow in fractures, ISDS effluent potentially can reach shallow ground water before concentrations of contaminants are reduced substantially.

One sample was collected from each of 12 municipal wells in Arapahoe, Douglas, and Elbert Counties, Colo., between March and October 2003. The wells were completed in the Dawson aquifer, the uppermost aquifer of the Denver Basin aquifer system. The northern part of the Dawson aquifer is located in the southern metropolitan area of Denver, and along with the three underlying aquifers of the Denver Basin, it is used primarily for drinking water and lawn irrigation (Robson, 1987). In the southern metropolitan area of Denver, where ground water is an important source of drinking water, urban development could make the water supply in the Dawson aquifer more vulnerable to contamination.

The few data currently (2004) available indicate that urban streams were the most vulnerable to contamination, with one or more wastewater chemicals being found in 100 percent of samples from urban streams, and with 57 of the 62 wastewater chemicals being detected in at least 1 sample from these sites. Concentrations also tended to be highest in urban streams compared to the other site types, with total concentrations above 1 microgram per liter (μg/L or part per billion) occurring in 8 of the 12 general-use categories (antioxidants, detergent metabolites, disinfectants, fire retardants, fragrances/flavors, nonprescription drugs, PAHs, and steroids) and total concentrations above 10 μg/L occurring in 3 of the 12 general-use categories (detergent metabolites, fire retardants, and nonprescription drugs).

Samples from the domestic wells generally had a lower number of wastewater chemicals detected and at lower concentrations compared to the urban streams sampled. However, a wide variety of chemicals also were detected (34 of 62) in the domestic wells. Total concentrations above 1 μg/L occurred in 7 of the 12 general-use categories (detergent metabolites, disinfectants, fire retardants, fragrances/flavors, plasticizers, solvents, and steroids).

The forested stream had fewer wastewater chemicals detected (11 of 62) and at lower concentrations compared to the urban streams and domestic wells sampled. Total concentrations above 1 μg/L occurred in only one general-use category (detergent metabolites).

The municipal wells sampled had the fewest wastewater chemicals detected (6 of 62) and the lowest concentrations measured of the four site types. Total concentrations were below 1 μg/L in all general-use categories.

No concentrations of individual chemicals exceeded currently (2004) established drinking-water standards in any of the samples; however, no standards have been established for most of these chemicals (U.S. Environmental Protection Agency, 2004). Concentrations of caffeine, DEET, nonylphenol, and triclosan, four of the more commonly detected chemicals at each site type, are shown in figure 4. The U.S. Environmental Protection Agency is developing aquatic-life criteria for nonylphenol because of its potential for endocrine disruption (U.S. Environmental Protection Agency, 2003), and triclosan is of concern because it may increase the antibiotic resistance of bacteria in the environment. Both chemicals were frequently detected in urban stream samples; triclosan also was present in samples from domestic and municipal wells.

Wastewater chemicals were detected more frequently and generally at higher concentrations in samples from urban streams and domestic wells than in samples from the forested stream and municipal wells. The results indicate

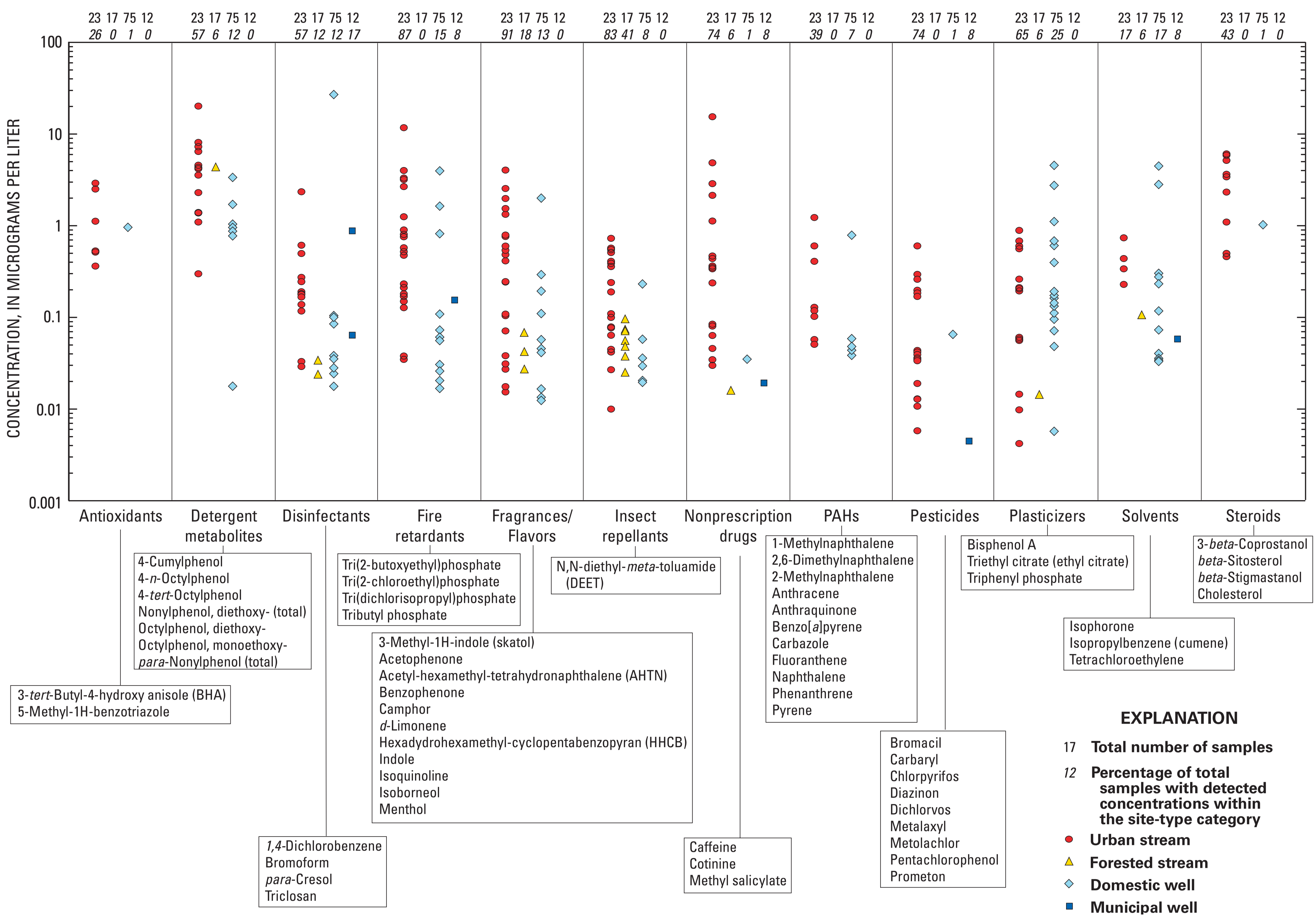

Figure 3. A new analytical method developed by the U.S. Geological Survey measures concentrations of 62 wastewater chemicals in water. Measurable concentrations of one or more of these wastewater chemicals were found in streams in urban and forested areas and in domestic and municipal wells.

EXPLANATION

17 Total number of samples

6 Percentage of total samples with detected concentrations within the site-type category

Urban stream

Forested stream

Domestic well

Municipal well

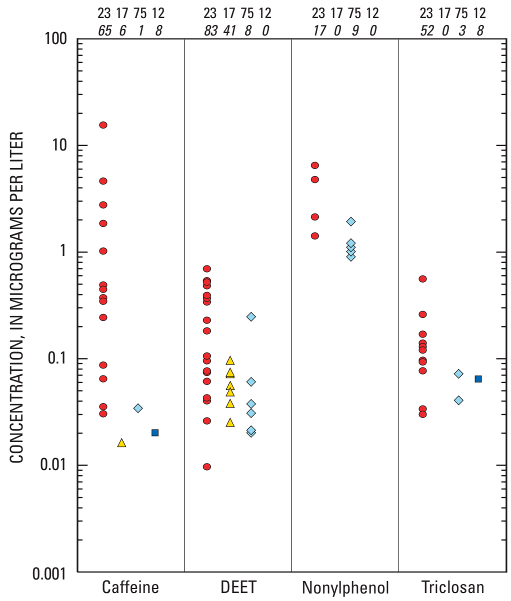

Figure 4. Caffeine, DEET, nonylphenol, and triclosan were four of the more commonly detected chemicals at each site type. The U.S. Environmental Protection Agency is developing aquatic-life criteria for nonylphenol because of its potential for endocrine disruption, and triclosan is of concern because it may increase the antibiotic resistance of bacteria in the environment.

that urban streams and domestic wells in Colorado may be vulnerable to contamination by wastewater chemicals. However, the detection of low concentrations of wastewater chemicals in the forested stream and deeper municipal wells indicates that these chemicals can be found in streams or ground water even in areas where there are no obvious sources of waste contamination nearby.

Where do we go from here?

Although data are available from only a limited number of sites in Colorado at this time, these results indicate that mixtures of wastewater chemicals are present at low concentrations at numerous, and sometimes unexpected, locations in the State. Other USGS studies have found hormones, antibiotics, and prescription drugs in urban streams receiving WWTP effluent across the Nation, including parts of the South Platte River (Kolpin and others, 2002; Barnes and others, 2002). The laboratory methods for measuring hormones, antibiotics, and prescription drugs in water are being developed and are nearing approval for general use by the USGS. Laboratory methods for the detection of wastewater chemicals in biosolids — solid or semi-solid residue generated during the treatment of domestic sewage and recycled as surface-applied fertilizer — also are being developed by the USGS.

For more than 100 years, the USGS has been successfully partnering with State and local agencies to fund water-resources studies through the Cooperative Water Program. These initial findings on wastewater chemicals in Colorado's streams and ground water, along with the new analytical methods being developed by the USGS, provide a starting point for further investigation into the occurrence, fate, and environmental effects of wastewater chemicals in Colorado and across the Nation.

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