Sacramento Top Delta Pesticide Source

Urban Sacramento appears to be the top contributor of pesticides to the Sacramento-San Joaquin Bay-Delta, according to new research from the University of California, Berkeley.

The purpose of the research was to find out where pyrethroid insecticides in the delta originate and what effects they have in the water bodies where they end up. According to the *Sacramento Bee*, the pesticides could be contributing to the collapse of the delta ecosystem by causing toxicity to tiny shrimp, a link near the bottom of the aquatic food chain. Pyrethroids can cause paralysis in the shrimp at a concentration of two parts per trillion.

Researchers collected water samples during both the dry season of 2008 and the wet season of either 2008 or 2009 from eight agricultural pump stations, six urban-runoff pump stations or storm drains, three municipal wastewater-treatment plants, and the Sacramento and San Joaquin rivers as they enter the delta. They also sampled transects along five creeks or rivers passing through urban areas after two to four rain events.

The scientists found that nearly all urban runoff contained the insecticides and caused toxicity to the shrimp. In addition, pyrethroids were present in two-thirds of effluent samples from wastewater-treatment plants, and in some cases caused toxicity. The Sacramento plant was the largest discharger of those studied, releasing at least 10 grams per day. Furthermore, three of the five creeks and rivers sampled, including the American River, showed toxicity repeatedly, over stretches up to 30 miles, after flowing through urban areas. The larger Sacramento and San Joaquin rivers can show localized impacts after storm events.

In contrast, only 30 percent of agricultural discharge samples contained pyrethroids. Shrimp toxicity was seen in only 10 percent of agricultural samples, but some of these occurrences were linked to the organophosphate insecticide chlorpyrifos.

According to the *Sacramento Bee*, pyrethoids are manufactured versions of insecticides produced naturally by some chrysanthemums. The pesticides have been used to replace more dangerous compounds such as diazinon and chlorpyrifos since about 2000. Pyrethroids are less harmful to humans and other mammals but turn out to be worse for aquatic life. They are commonly used by both pest-control companies and homeowners to kill insects.

The *Bee* reported that the California Department of Pesticide Regulation began a process to regulate pyrethroids in 2006. The regional water quality control board funded the Berkeley study and plans to declare several waterways impaired due to the presence of these insecticides.

Visit www.sacbee.com and media.sacbee.com/smedia/2009/07/10/17/0712pesticides.source.prod_affiliate.4.pdf.

Ogallala Quality Declining

Although water produced by the High Plains, or Ogallala, Aquifer is currently acceptable for multiple uses including human consumption, heavy water use and leakage down inactive irrigation wells are causing long-term gradual increases in concentrations of contaminants in the aquifer, according to a U.S. Geological Survey report issued in July.

In the future, contaminants such as nitrate and dissolved solids will be present from the water table to deeper parts of the aquifer where drinking-water wells are typically screened, creating implications for future use of the aquifer. In addition, once the aquifer is contaminated, remediation will be a slow process—the groundwater in some parts of the aquifer is 10,000 years old and travels slowly.

The High Plains Aquifer provides water to eight states including Colorado, New Mexico, and Texas, and is the most heavily used groundwater source in the country. USGS scientists analyzed water for more than 180 chemical compounds and physical properties in about 300 private domestic wells, 70 public-supply wells, 50 irrigation wells, and 160 shallow monitoring wells sampled between 1999 and 2004. The study also assessed the transport of water and contaminants from land surface to the water table and deeper zones used for supply, in order to predict changes in concentrations over time.

Currently, more than 85 percent of the 370 wells used for drinking water meet federal drinking-water standards, and most of the contaminants that exceeded standards were from natural sources.

Visit www.usgs.gov. See Gurdak, J.J., P.B. McMahon, K.F. Dennehy, and S.L. Qi, 2009. Water quality in the High Plains aquifer, Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming, 1999–2004, USGS Circular 1337, pubs.usgs.gov/circ/1337/.

Studies Agree: Colorado Deliveries Threatened

Two independent 2009 studies show water deliveries from the Colorado River may be significantly threatened over the next half-century. Both found that the current approach to managing the

continued on next page

Colorado River system is not sustainable. Climate-change models generally show that a 6 to 20 percent reduction in stream runoff in the Southwest by midcentury is likely, and both sets of researchers used this range to evaluate how reservoir storage and deliveries might be affected.

The first study, by researchers at Scripps Institute of Oceanography, updates their 2008 study that predicted a 50 percent chance that Lake Mead could dry up by 2020. The 2009 results showed that a 10 percent reduction in average annual runoff compared to current rates would mean water deliveries would not be met nearly 60 percent of the time by 2050. A runoff reduction of 20 percent increased the likelihood of missed deliveries to 88 percent. The authors emphasized that current deliveries are likely not sustainable and suggested that scheduled deliveries should be changed to more realistically reflect actual conditions.

The second study, by researchers at the University of Colorado, Boulder, analyzed how reservoir storage would be affected by 0, 10, and 20 percent decreases in Colorado River flow under various management strategies. For all climate-fluctuation and management-alternative scenarios tested, the risk of fully depleting reservoir storage in any given year remained below 10 percent through 2026. However, a climate-change-induced flow reduction of 10 percent would deplete reservoir storage more than 25 percent by 2057. A 20 percent reduction correlated to greater than 50 percent depleted storage.

The University of Colorado researchers point out that the resiliency of the system in the short term should not cause complacency, as policy options may be far more limited by 2026. Working to increase flexibility in water-resource management may help deal with the threats to the water supply caused by population growth, likely multi-year droughts, and potential climate-change-induced streamflow reductions.

See Barnett, T.P. and D.W. Pierce, 2009. Sustainable water deliveries from the Colorado River in a changing climate. Proc. Nat. Acad. Science, 106(18): 7,334-7,338. Also see Rajagopalan, B., K. Nowak, J. Prairie, and others, 2009. Water supply risk on the Colorado River: Can management mitigate? Water Resour. Res., 45, W08201, doi:10.1029.2008WR007652.

Central Valley Groundwater Declining, Threatening Aqueduct

Groundwater levels are declining in the southern portion of San Joaquin Valley in California, USGS researchers reported in July. However, the abundance of coarse-grained soils in this area offers promise for large-scale artificial groundwater recharge.

San Joaquin Valley is part of the 400-mile-long Central Valley, which contains the largest groundwater system in California. The aquifer yields one-fifth of all groundwater pumped in the nation, much of it used for agriculture. Based on data through 2003, researchers found that, unlike in southern San Joaquin Valley, groundwater levels in Sacramento Valley and the northern portion of San Joaquin Valley are generally stable.

However, ongoing drought in the state is increasing pressure on groundwater supplies as landowners drill more and deeper wells and pump more water, causing groundwater levels to fall. This is consistent with previous droughts of the 1970s and 1980s.

According to the *Sacramento Bee*, the decline of groundwater levels, which has caused subsidence in the Central Valley in the past, threatens the stability of structures like the California Aqueduct, which transports drinking water to over 20 million people.

The Associated Press reported in July that the Metropolitan Water District of Southern California and other state water users have contracted with USGS to monitor 70 miles of the California Aqueduct by satellite, at a cost of $255,000. According to the article, current pumping due to the drought is approaching levels that in the 1970s caused the canal to bow several feet, requiring emergency repairs.

The research is part of the USGS Groundwater Resources Program's $1 million, four-year study of Central Valley groundwater; see page 38 for additional information.

Visit www.usgs.gov, www.sacbee.com, and google.ap.com. Also see Faunt, C.C., ed., 2009. Groundwater Availability of the Central Valley Aquifer, California, USGS Professional Paper 1766, pubs.usgs.gov/pp/1766/.

Great Salt Lake Exhales Selenium

The Great Salt Lake can remain healthy for birds despite its high selenium loads because it apparently vaporizes selenium into the atmosphere, reported the *Salt Lake Tribune* in June.

Excessive selenium in water bodies poisons birds, resulting in weakened egg shells, deformed chicks, and crippled embryos. The Kesterson Reservoir in California famously caused a massive die-off in birds in the 1980s as a result of elevated selenium.

Researchers at USGS and the University of Utah found that although the Great Salt Lake has no outlets to carry selenium away, chemical transformations of selenium in the salty water allow surface air to remove it, reported the *Tribune*. Additionally, a paper in *Environmental Science & Technology* suggests that phytoplankton and bioherms (mounds of organic material) may be producing volatile selenium. The estimated annual flux of volatile selenium into the atmosphere was 3,200 pounds per year. In a separate USGS report, the annual load to the lake was estimated to be about 3,450 pounds.

According to the *Tribune*, the state of Utah plans to fund additional studies regarding selenium in the food chain and its movement around the lake. Researchers also hope to determine if the rapid increase in selenium in the last 18 months is a long-term trend or part of a cycle.

Visit www.sltrib.com. See Diaz, X., W.P. Johnson, W.A. Oliver, and D.L. Naftz, 2009. Volatile selenium flux from the Great Salt Lake, Utah, Environ. Sci. Tech., 43(1): 53-59. Also see Naftz, D.L., W.P. Johnson, M.L. Freeman, and others, 2009. Estimation of selenium loads entering the south arm of Great Salt Lake, Utah, from May 2006 through March 2008, USGS Sci. Invest. Rept. 2008–5069, pubs.usgs.gov/sir/2008/5069/.

Gallium Improves Water Purification

By replacing a single atom in a molecule widely used to purify water, researchers at Sandia National Laboratories have created a more effective decontaminant that lasts longer than purification products currently on the market.

The decontaminant is made by substituting an atom of gallium in the center of an aluminum-oxide cluster that is often used as a coagulant in water-purification processes. Gallium makes the reagent more stable and effective. The resulting coagulant maintains its electrostatic charge more reliably than conventional coagulants, allowing it to attract and bind contaminants exceptionally well. In addition, it resists converting to larger, less-reactive aggregates before it can react with contaminants, thereby providing a longer shelf life.

The substitution is performed by dissolving aluminum salts in water, dissolving gallium salts into a sodium-hydroxide solution, and then slowly adding the sodium-hydroxide solution to the aluminum solution while heating.

The research was published in the July 2009 issue of *Environmental Science & Technology*. The project, which also tested germanium but found it to be less effective than an all-aluminum coagulant, involved transmission electron microscopy of bacteriophages binding to the altered material as well as mass spectroscopy of the aluminum clusters in solution.

Sandia has applied for a patent on the material, which removes bacterial, viral, and other organic and inorganic contaminants from river water destined for human consumption and from wastewater in treatment plants prior to its discharge to the environment. The new reagent performs well under a wide range of conditions, including fluctuations in pH, temperature, and turbidity that are common in natural water sources.

Visit www.sandia.gov. See Stewart, T.A., D.E. Trudell, T.M. Alam, and others, 2009. Enhanced water purification: a single atom makes a difference, Environ. Sci. Tech., 43(14): 5,416-5,422.

continued on next page

New Hydrologic Modeling Center at UC Irvine

The University of California at Irvine has been awarded $2.5 million to use satellites and field research to more accurately determine how much water exists in California and where it is located.

The money comes from the University of California Office of the President and establishes a Center for Hydrologic Modeling led by James Famiglietti, a professor of earth system science and civil and environmental engineering specializing in hydrology and climate. The center's research will focus on combining computer models with observations to ascertain how much water is in aquifers, soil, and snowpack. According to Famiglietti, "There's been too large of a gap between decision-makers and scientists over the water situation in California. We're going to help bridge that gap."

Visit www.uci.edu.

New Aspects of Water's Structure Uncovered

Recent work at the U.S. Department of Energy's SLAC National Accelerator Laboratory (operated by Stanford University) and several universities in Sweden and Japan is shedding new light on water's molecular idiosyncrasies, offering insight into its strange bulk properties. In all, water exhibits 66 known anomalies, including a large heat capacity, high surface tension, and strangely varying density—reaching a maximum at about 4 degrees Celsius.

How ice molecules arrange themselves is well established: they form a tight tetrahedral lattice. According to the current textbook model, liquid water should have a similar but less structured tetrahedral form, since heat creates disorder and breaks bonds. As ice melts, the theory says, tetrahedral bonds tend to weaken and break apart, resulting in a smooth distribution around distorted, partially broken tetrahedral structures.

But recent experiments on liquid water by SLAC scientist Anders Nilsson and colleagues suggested instead that two distinct structures, either very disordered or very tetrahedral, exist regardless of temperature. They performed the experiments using small-angle x-ray scattering.

In a paper published in the *Proceedings of the National Academy of Sciences*, the researchers revealed the additional discovery that the two types of structures are spatially separated, with the tetrahedral structures existing in clumps made of up to about 100 molecules surrounded by disordered regions; the liquid is a fluctuating mix of the two structures at temperatures ranging from ambient to near boiling. As the temperature increases, fewer clumps exist; but they are always present to some degree, in clumps of a similar size. The researchers also discovered that the disordered regions themselves become more disordered as the temperature rises.

This more detailed understanding of the molecular structure and dynamics of liquid water at ambient temperatures mirrors theoretical work on supercooled water. In this state, theorists postulate, the liquid is made up of a continuously fluctuating mix of tetrahedral and more disordered structures, with the ratio of the two depending on temperature—just as Nilsson and his colleagues found to be the case with water at ambient temperatures.

This new work explains, in part, the liquid's strange properties. Water's density maximum can be explained by the fact that the tetrahedral structures have a lower density that does not vary significantly with temperature, while the more disordered, higher-density regions become even more disordered and therefore less dense with increasing temperature. Likewise, as water heats, the percentage of molecules in the more disordered state increases, allowing this excitable structure to absorb significant amounts of heat, which leads to water's high heat capacity. ■

Visit home.slac.stanford.edu. See Huang, C., K.T. Wikfeldt, T. Tokushima and others, 2009. The inhomogeneous structure of water at ambient conditions, Proc. Nat. Acad. Science doi:10.1073/pnas.0904743106.