Elevated Nitrate, Pesticides, and Pesticide Degradates in Ground Water and Lakes on the Lake Wales Ridge, a Unique Hydrologic and Biologic Region in Central Florida

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The landscape, hydrology, and ecology of Lake Wales Ridge, central Florida, are unique in many respects. The Ridge is the highest and most prominent topographic feature in peninsular Florida and contains one of the largest collections of rare and endangered species in the United States (Dobson and others, 1997), one of the highest concentrations of endemic species in North America (Martin, 1998), and more than 200 lakes, most of which are seepage lakes with significant ground-water inflow. Lake Wales Ridge (subsequently referred to as 'the Ridge') is also one of the most intensely cultivated citrus regions in the world, with citrus groves covering about 25 percent (170 square miles) of the land area. Geologically, the Ridge is underlain by highly permeable marine sands forming relict Miocene-Holocene paleoislands which support some of the oldest ecologic communities in Florida. Ground water and surface water are closely linked in this region where ground-water inflow contributes more than 80 percent of the net water input to some lakes (Sacks and others, 1998). Ground water is the primary drinking-water supply in this region. The unconfined surficial aquifer supplies drinking water for some rural wells, and recharges water to the underlying Upper Floridan aquifer which is the primary municipal water supply.

Ground water on the Ridge is extremely vulnerable to contamination due to several factors including the combination of highly permeable sandy soils and seasonally high rates of rainfall. In addition, these soils contain little organic matter, reducing the potential for sorption of pesticides and for denitrification. During the late 1980s and 1990s, elevated concentrations of nitrate and pesticides in ground water on the Ridge prompted development of restrictions specific to the Ridge on the usage of agricultural chemicals, as well as remedial actions to remove potential contaminants from some rural drinking-water supplies. Elevated nitrate concentrations, locally exceeding 8 milligrams per liter (mg/L), have been observed in Ridge lakes in citrus areas (Romie, 2000), and a statewide survey (USEPA, 1990) indicated that 89 percent of Florida wells yielding nitrate concentrations above the USEPA maximum contaminant level[3] of 10 mg/L occurred in the ridge citrus regions.

Two USGS studies, in partnership with state agencies, focus on agricultural chemicals in ground water and lakes in citrus areas on the Ridge. The ground-water study, initiated in 1998, is a regional assessment of 29 pesticides and degradates that includes ongoing sampling of 31 wells (Choquette and others, 2003; web site: *http://fisc.er.usgs.gov/Lake_Wales_Ridge/index.html*). The lake study, initiated in 2003, is a reconnaissance sampling of eight seepage lakes in Ridge citrus areas. Few previous studies have systematically documented regional short-term and long-term variations in pesticides in ground water, or the occurrence and variability of pesticides in small to moderately sized lakes (5 to 100 acres).

Sampling of ground water and lakes on the Ridge has revealed elevated concentrations of nitrate, pesticides, and pesticide degradates. During 1999 to 2004, nitrate concentrations in ground water exceeded the USEPA MCL one or more times at 90 percent of the network wells. Twelve targeted pesticides and degradates have been detected in ground water from these wells, with as many as eight different pesticides or degradates occurring in ground water from some wells. Concentrations of five targeted pesticides or degradates (aldicarb sulfoxide and sulfoxone, simazine, bromacil, and diuron) have exceeded Florida's

human-health guidance concentrations[4] in one or more samples from the wells, although such exceedances have been limited to less than five percent of all samples. Concentrations of all pesticides detected in Ridge ground water have exceeded national maximums from the USGS National Water-Quality Assessment (NAWQA) monitoring network of more than 3,375 wells for the period 1992-2001 (web site: *http://ca.water.usgs.gov/npsp/*). Pesticide concentrations in ground water often show significant short-term variability and concentrations of some pesticides appear to be increasing over time (Choquette and others, 2005).

Compared to the ground-water study, the lake study includes additional target pesticides and lower laboratory detection limits. Concentrations of pesticides and degradates detected during 2003-2004 reconnaissance sampling from four Ridge lakes generally were lower than the 1999-2004 concentrations observed in ground water. However, the lake concentrations for most detected pesticides appear to be relatively high when compared nationally to streams in agricultural areas sampled by the USGS NAWQA program (web site: *http://ca.water.usgs.gov/npsp/*). Concentrations in the lake samples have not exceeded human-health guidance levels or aquatic-life criteria. A total of nineteen different pesticides and pesticide degradates have been detected in the lake samples, and six or more target pesticides and degradates were detected in most (75%) of the samples. In lake samples, the highest concentrations, ranging from 0.1 to 17.1 μg/L, included: norflurazon, desmethyl norflurazon, 2,4-D, bromacil, aldicarb sulfoxide and sulfone, hydroxysimazine, chlordiamino-s-triazine (CAAT or DDA), chloroethylamino-s-triazine (CEAT or DIA), and diuron. Detection frequencies for these compounds ranged from 25 to 100 percent of the samples.

Furthering our understanding of the transport and fate of agricultural chemicals on the Ridge, and their effects on Ridge ecosystems presents a number of opportunities for interdisciplinary collaboration. Process-oriented, local-scale studies are needed to track the transport and fate of nitrate, pesticides, and pesticide degradates in soils, ground water, and lakes, including the effects of atmospheric transport and of biogeochemical processes in lake sediments. Much is unknown regarding the chronic toxicity of pesticides, chemical mixtures, and pesticide degradates to non-target organisms. There have been no studies to date to assess the potential impacts of elevated concentrations of citrus pesticides and pesticide degradates on the biologic communities of Ridge lakes. Additional factors that make this research particularly compelling include recent data indicating adverse effects of low, ecologically relevant concentrations of pesticides on non-target organisms (Hayes and others, 2002; Gross and others, 2003; Barbash, 2004); the incomplete removal of simazine from standard municipal water-filtration systems (Coupe and Blomquist, 2004); and the potential for increased toxicity of simazine when combined with elevated nitrate concentrations (U.S. Dept. of Health and Human Services, 2004).

References

Barbash, J.E., 2004, The Geochemistry of Pesticides in Treatise on Geochemistry, Vol. 9, Elsevier Ltd, p. 541-577.

Choquette, A.F., Moore, D.K, Dehaven, E.C., Haber, J.D., and Turner, R.M., 2003, A litmus area for transport of agricultural chemicals into ground water and lakes, central Florida: American Water Resources Assoc. Conference, "Agricultural Hydrology and Water Quality", Kansas City, MO., May 2003, Proceed., AWRA Technical Pub. Series No. TPS-03-1.

Choquette, A.F., Turner, R.M., Haber, J.D., Lucas, P.A., Daiker, D.H., and DeHaven, E.C., 2005, Temporal variability of agricultural chemicals in ground water and implications for water-quality sampling design: 15th Annual Tennessee Water Resources Symposium, April 2005, American Water Resources Association, Proceedings.

Coupe, R.H., and Blomquist, J.D., 2004, Water-soluble pesticides in finished water of community water supplies: Journal of the American Water Well Association, v. 96, no. 10, p. 56-68.

Dobson, A. P., Roderiguez, J., Roberts, W., and Wilcove, D., 1997, Geographic distribution of endangered species in the United States: Science, v. 275, p. 550-553.

Gross, T.S., Smith, J., Wiebe, E., Sepulveda, M., Carr, J. Du Preez, L., Kendall R., Soloman, K., Smith, E., Van Der Kraak, G., 2003, An evaluation of gonadal anomalies and agrichemical exposures for the cane toad (Bufo marinus) in south Florida: Annual Meeting of the Soc. of Environ. Toxicology and Chemistry, Proceedings, Nov. 2003, Austin, TX.

Hayes, T.B., Collins, A., Lee, M., Mendoza, M, Noriega, N., Stuart, A.A., and Vonk, A., 2002, Hermaphroditic, demasculinized frogs after exposure to the herbicide atrazine at low ecologically relevant doses: Proceed. of the National Academy of Science, USA, v. 99, no. 8, p. 5476-5480.

Martin, T., 1998, Florida's Ancient Islands: the Lake Wales Ridge: Florida Dept. of Environmental Protection, 16 p. [http://www.archbold-station.org/fai/index.html]

Romie, Kenneth, 2000, Water chemistry of lakes in the Southwest Florida Water Management District: 61 p. and Appendices.

Sacks, L.A., Swancar, Amy, and Lee, T.M., 1998, Estimating ground-water exchange with lakes using water-budget and chemical mass-balance approaches for ten lakes in ridge areas of Polk and Highlands Counties, Florida: U.S. Geological Survey Water-Resources Investigations Report 98-4133, 52 p.

U.S. Dept.of Health and Human Services, 2004, Interaction profile for: atrazine, deethylatrazine, diazinon, nitrate, and simazine: Agency for Toxic Substances and Disease Registry, Draft Document, 63 p. (available online at: www.atsdr.cdc.gov/iteractionprofiles/ip10.html)

U.S. Environmental Protection Agency, 1990, National Pesticide Survey: Project Summary: USEPA Report Number 570990NPS6, 13 p.

[3] U.S. Environmental Protection Agency maximum contaminant level (MCL) for drinking water.

[4] These values correspond to the USEPA MCL's and, for compounds that do not have a MCL, the Florida Department of Environmental Protection target cleanup levels (http://fdep.ifas.ufl.edu/, accessed 3/8/2005)