TEXAS WATER RESOURCES INSTITUTE

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Combined Local and State Efforts Restore Aquilla Lake

Reduced Levels of Herbicide Atrazine Make Lake a Safe Source for Drinking Water

By April Smith

Texas Cooperative Extension (TCE) played a big role in helping reverse a serious pollution problem in Aquilla Lake in Hill County, according to Dr. Allan Jones, director of the Texas Water Resources Institute (TWRI) and close collaborator of TCE.

The Texas Commission on Environmental Quality (TCEQ) has confirmed, and extensive sampling now shows, that Aquilla Lake has been fully restored as a safe source for drinking water because of the combined efforts of local farmers and facilities, regional agencies and state government.

"The range of participation from the state level to the local level was crucial in reestablishing Aquilla Lake as a source of drinking water," said TCEQ Chairman Kathleen Hartnett White. "The Lake is a protected and precious resource to the people of Hill County, and we will continue to work with local farmers to ensure it remains so."

TCEQ listed the body of water as "impaired" after high levels of atrazine, an inexpensive, effective weed suppressant used on crops, were detected. Atrazine can wash off from recently treated fields during rain showers into ditches and streams that eventually carry the herbicide into the lake.

In response to the listing, a broad-based coalition with several agencies and organizations was initiated to lessen atrazine runoff. Active participants include the Texas Department of Agriculture, TCEQ, Texas State Soil and Water Conservation Board (TSSWCB), the Texas Watershed Protection Committee and TCE.

The coalition prepared a total maximum daily load (TMDL) analysis that identified the sources of atrazine pollution and developed a plan to reduce atrazine pollution. More than 600 potential contamination sources, such as fertilizer and pesticide fields, were identified in the Aquilla watershed.

The TMDL could have prohibited regional farmers from using this economical, popular herbicide on crops unless atrazine runoff could be controlled. Some estimates suggested farmers in the region could lose thousands of dollars if atrazine were restricted. In response to this, the coalition identified sources of cost-share funding, making it more economical for farmers to adopt best management practices (BMPs) to improve water quality.

At the same time, TCE teamed up with several soil and water conservation districts in the region to personally work with farmers to show them how atrazine was affecting the quality of the lake and to implement farming methods to reduce atrazine levels. Area farmers then took the initiative to re-examine their own growing practices. Since this coordinated effort began, almost 100 percent of area farmers have voluntarily adopted new practices that prevent or reduce atrazine runoff to area streams.

*See **Aquilla** on page 2*

IN THIS ISSUE

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Aquilla

continued from cover

"Due to the level of cooperation, we were able to solve the atrazine problem in only a few years," said Monty Dozier, Extension Specialist in the Department of Soil and Crop Sciences at Texas A&M University. "Everybody came together to create a plan and we worked with the farmers and other stakeholders to make it succeed."

Since high atrazine levels were detected in 1997, the Aquilla Water Supply District, which treats lake water and delivers it to area residents, added additional treatment methods at the drinking water plant. The District has also carefully monitored treated water in the plant to assure they are delivering safe drinking water to the public.

Water samples collected from the lake from 2001 through 2003 indicate atrazine concentrations in the reservoir are down by 60 percent, bringing annual averages for atrazine well below the required safety level for treated drinking water.

"I've been working with water quality issues for more than 10 years, and I've never seen a project that's been this successful," said Kevin Wagner of the TSSWCB.

"This is an excellent example of governmental entities, involving regulatory, educational and financial assistance, working on a voluntary basis with landowners to achieve desired environmental goals," said Jones of the TWRI.

TRWD Wetlands Treat Trinity

by Kellie Potucek

One might say picturesque scenery is reason enough to build wetlands in North Central Texas. However, researchers are finding the beauty of wetland development goes far beyond the view.

Tarrant Regional Water District (TRWD) partnered with Texas Parks and Wildlife to establish 250 acres of new wetlands about five miles from Richland-Chambers Reservoir. The wetlands serve to assist in the treatment of river water, which contains substantial amounts of wastewater from the Dallas/Fort Worth area during certain times of the year. The project diverts flows from the Trinity River and channels them through constructed wetland cells. Serving as natural filters, wetlands remove excess nutrients, sediment, and other contaminants. After the project's next phase of development, the treated water will be returned to Richland-Chambers Reservoir for eventual reuse by District customers.

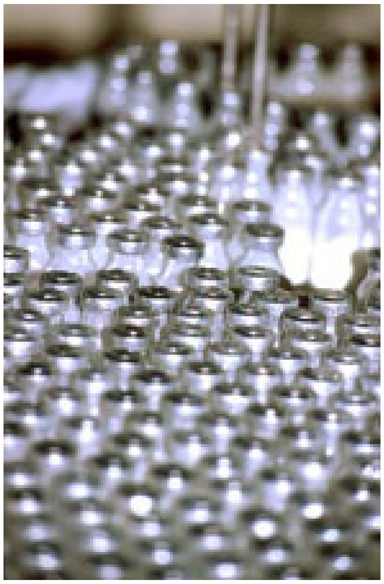
The advantages of this wetland water reuse project are abundant. By tapping into an existing water resource, water originating from District reservoirs can be recycled or reused. The reuse project will ultimately provide a 30 percent increase in water supply from Richland-Chambers Reservoir. The additional water will serve the needs of up to 300,000 people annually, postponing the need to build new reservoirs. Additionally, water quality measurements indicate that water flowing from the new wetland is more pure than water coming from natural tributaries. Furthermore, the habitat created by this natural system compliments the goals of the Texas Parks and Wildlife Department on their Richland Creek Wildlife Management Area. This flourishing wetland ecosystem beckons thousands of migratory waterfowl and shorebirds as well as bald eagles that make Richland-Chambers Reservoir their winter home.

The TRWD wetland development project was honored in Texas with the American Council of Engineering Companies (ACEC) 2004 Award for Engineering Excellence in Water and Wastewater. This qualified the project to compete against over 150 entries in a national competition. Again, the project topped the Water and Wastewater category, winning the ACEC 2004 Grand Award for Engineering Excellence.

The Richland-Chambers wetlands are planned to ultimately grow to 2000 acres. Plans to implement similar wetland water reuse programs in other areas of Texas are currently underway. For additional information about the project, visit www.trwd.com.

Scientists Explore if Pharmaceuticals Alter Quality of Rivers, Streams

by Ric Jensen



Might some of the prescription drugs people regularly take end up in rivers and streams and, if so, what might be the consequences for human health and plants and animals in the environment?

This topic is receiving increased attention from scientists throughout Texas and nationally. Studies are now under way at Southern Methodist University (SMU), Baylor University, Texas Tech University, and Texas A&M University to learn more about this issue.

The basic problem is that several prominent studies suggest that low concentrations of a wide range of pharmaceuticals are being detected in surface waters in the United States and throughout the world. For example, a 2002 study by the U.S. Geological Survey showed that more than 30 pharmaceuticals were present in much of the nation's surface water.

At the same time, research indicates that very low levels of some of these contaminants might be disturbing the endocrine systems of fish and amphibians, possibly threatening the ability of these animals to reproduce and causing other behavioral abnormalities. For example, research suggests that male fish exposed to estrogen often produce chemicals and egg yolks that are typically only generated by female fish.

The good news is that chemicals that cause changes in hormone levels do not seem to pose an immediate human health risk and are not showing up in drinking water supplies. According to Jim Davenport, leader of the water quality standards team for the Texas Commission on Environmental Quality, Texas has not yet developed regulations or standards for hormones or pharmaceuticals because national standards have yet to be established. "The issue is a concern to us, but there isn't much we can do until we get more criteria to create standards, if they are needed," he said.

At SMU, researcher John Easton of the Environmental Engineering Department is leading studies funded by Region 6 of the U.S. Environmental Protection Agency to identify levels of such hormones as estrogen, testosterone, and progesterone in surface waters of the North Bosque River. Later, he will compare levels of hormones from that watershed to concentrations near wastewater treatment plants in the Dallas area and will attempt to correlate pharmaceutical concentrations with land use.

"There are so many cattle in the North Bosque and they create so much waste that it seems possible that hormones produced by the dairies may build up in the region's rivers," he said. "We want to compare how levels of hormones in surface waters in that region compare to urbanized sites." In addition, one of Easton's graduate students, Adrian Dongell, was recently awarded a Texas Water Resources Institute grant to examine how well wastewater treatment plants treat and remove hormones and pharmaceuticals.

Research at Baylor University is focusing on a slightly different issue—investigating the effects of pharmaceuticals on aquatic species in streams that are often comprised largely of treated wastewater. Bryan Brooks, a researcher in the Center for Reservoir and Aquatic Systems Research, is leading efforts to examine how residuals from such commonly used drugs as steroids, cholesterol fighting beta blockers and antidepressants may be affecting the environment. Much of Brooks' research is concentrated in the Pecan Creek watershed near Denton, because streams in that area are effluent-dominated.

"We need to determine the levels of different types of pharmaceuticals that are present in river and stream segments and then examine the risks that are posed to aquatic species," Brooks said. "If we find that fish, amphibians, and other species are being harmed, then we need to determine if a red flag should go up that may prompt us to identify the crucial questions and learn more."

*See **Pharmaceuticals** on page 9*

Total Maximum Daily Loads

Section 303(d) of the 1972 Clean Water Act (CWA) requires all states to develop a list of their state's impaired water bodies (rivers, lakes, estuaries). The 303(d) list consists of those water bodies that do not meet state regulatory water quality standards. The CWA also requires all states to establish priority rankings for waters on the 303(d) list. States must develop Total Maximum Daily Loads (TMDLs) for these waters based on their individual priority ranking.

A TMDL is a pollution budget for a specific water body. It is the maximum amount of a pollutant that can be released into a water body without causing it to become impaired and/or violate state water quality standards. The maximum allowable amount is the sum of pollutant loads from point, nonpoint, and natural sources. A TMDL must also include a margin of safety to allow for any uncertainties in the scientific methods used to derive the load allocation, such as water quality monitoring assumptions.

Wasteload Allocation (point sources)
+
TMDL = Load Allocation (nonpoint sources and natural background sources)
+
Margin of Safety

History of TMDLs

TMDLs were first required by the CWA of 1972. Initially, states and the Environmental Protection Agency (EPA) focused on the point source part of the TMDL, called the wasteload allocation. Some TMDLs were developed but, until recently, very little national emphasis or resources were placed on developing the scientific tools necessary to produce TMDLs for complex problems. It is also important to note that prior to the development of TMDLs, some level of technology and water quality based controls had been required from point sources under the CWA.

The absence of TMDLs does not mean that no discharge controls are in place on state water bodies. Many times controls of point sources are adequate to protect water uses without a TMDL.

Several years ago, however, citizen organizations began bringing legal actions against the EPA, seeking the complete listing of impaired waters and development of TMDLs as required by the CWA. To date, there have been about 40 legal actions in 38 states, including Texas. However, since Texas began doing TMDLs in 1996, the EPA has not been sued regarding the state's 303(d) list or TMDL development. The EPA is under a court order or consent decree in many other states to ensure that TMDLs are established. The CWA authorizes the states to develop TMDLs, but if the states do not develop the TMDLs, then the EPA must develop them.

One approach EPA used to address the large numbers of lawsuits was to revise the current TMDL regulations. Those draft regulations were issued in 1999. After the Agency's review and consideration of more than 34,000 comments, the TMDL rule was finalized on July 13, 2000. The EPA temporarily suspended the 2000 TMDL regulations before they could take effect, and repealed them completely in March 2003. Therefore, the regulations adopted by the EPA in 1992 remain in effect today.

The 1992 rule mandates that states list impaired water bodies, as required under Section 303(d) of the CWA, and develop TMDLs for those water bodies. By law, the EPA must approve or disapprove state 303(d) lists and TMDLs. If a state submission is disapproved, the EPA must establish a new 303(d) list and/or develop new TMDLs.

TMDL Action

In Texas, TMDLs are developed through a cooperative process involving the people and organizations who will have a stake in implementing them. After the final draft of a TMDL document is completed by TCEQ staff or contractors, it goes through the adoption process. The Commission, made up of three officials appointed by the governor, plays a big role in TMDL approval. First, the TMDL Program seeks permission from the Commission to publish the TMDL for public comment for a period of 30 days. If permission is given, the public comment period is advertised on TCEQ's Web site, in the *Texas Register*, and in area newspapers. The TCEQ also holds a public meeting to receive comments from citizens, organizations, and interest groups, in addition to accepting written comment.

After the public comment period is complete, the TCEQ and any partner agencies review the comments, make changes to the TMDL document as needed, and publish a response to public comment.

When the final TMDL document is complete, the TMDL Program presents it to the Commission for adoption at a public meeting. Notice of this meeting is given in the *Texas Register* and on the TCEQ Web site. If the Commission adopts the TMDL, it is submitted to the EPA for approval.

In cases where another agency is the co-author of a TMDL document, that agency may also take the document before its governing commission or board for approval or adoption. This is not required, however.

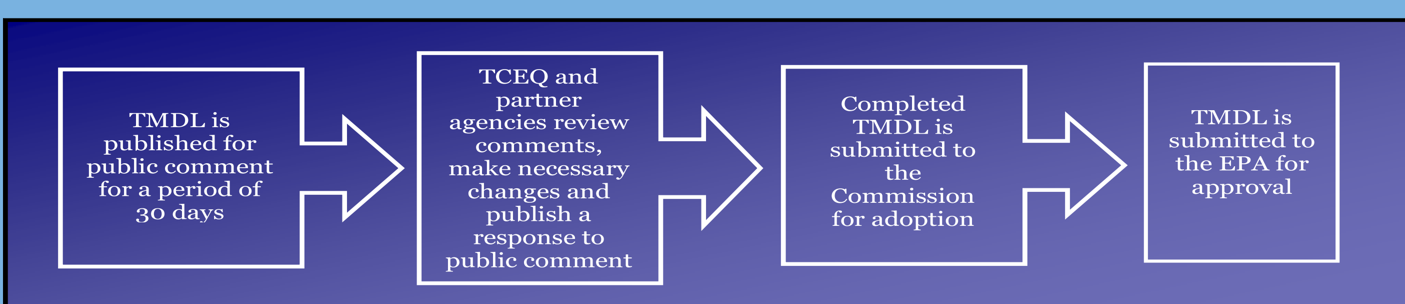
As soon as the TMDL is adopted by the Commission, the TMDL Program begins work on developing an Implementation Plan (IP). An IP puts the TMDL into action by outlining the steps necessary to reduce pollutant loads through regulatory and voluntary activities. IPs describe the actions that local, regional and state organizations must take to reduce pollutant loads to levels established in TMDLs.

The IP goes through a stakeholder process and public comment period almost identical to that of the TMDL. The final IP is submitted to the Commission for approval at a public meeting. The IP is not subject to approval by the EPA.

After a TMDL is approved by the EPA, the impairment is removed from the 303(d) List. The impairment is downgraded to Category 4 of the Water Quality Inventory, which includes waters that do not meet standards, but for which a TMDL is complete or a TMDL is not needed. It is usually a long while before implementation is completed and water quality is restored.

Recognizing that it is difficult to predict improvements in water quality with so many different variables in play, IPs are often written to put activities into practice in phases. Checkpoints are set up along the way to determine whether water quality is improving as implementation moves forward. If sufficient progress is not being made toward meeting the load allocation when one of these checkpoints is reached, the IP may be revised, or a new, more stringent phase may be automatically triggered. This adaptive approach ensures that adjustments are made as needed to reach the goal of restoring the impaired uses of the water body.

A TMDL remains in effect until it is revised or updated, which would only occur if conditions in the watershed changed substantially.



The Health of Texas Waters

Revamped report provides more information on water quality

by April Smith

The TCEQ's biennial report on the condition of Texas water bodies is being presented in a more comprehensive manner than previously. The report, which is available online, also includes an easy way for Texans to check the water quality status of more than 700 lakes, rivers and streams.

The *2002 Draft Texas Water Quality Inventory and 303(d) List* combines two separate reports required under the federal Clean Water Act: the 305(b) water quality inventory and the 303(d) list of waters that do not meet the state's surface water quality standards due to contamination or other problems.

The new format also assigns all bodies of water to one of five categories based on levels of water quality. These rankings show how many waters meet their "designated uses," such as for drinking water, swimming, fishing and oyster harvesting and a healthy environment for fish and other aquatic species.

New Classifications

The revamped report was prompted by the US Environmental Protection Agency, which recommended that states use the new format to better characterize the status of water bodies and more clearly explain cleanup strategies. Starting with the 2002 report, which awaits final approval from the EPA, the TCEQ uses the following classifications to grade water bodies:

Category 1: Attaining the state water quality standards.

Category 2: Attaining some designated uses; insufficient information is available to determine whether the remaining uses are attained.

Category 3: Lacking sufficient data to determine whether any designated uses are attained.

Category 4: Failing to meet one or more designated uses; a TMDL is not required or has been completed.

Category 5: Failing to attain water quality standards; a TMDL or some other action is required.

Of the 731 water bodies assessed in Texas in 2002, the 298 water bodies listed in Category 5 receive the most attention from the TCEQ. They are assigned to one of three subcategories (A, B and C), depending on how the TCEQ intends to address individual water quality problems. For waters in Category 5A, TMDLs will begin in the next several years, depending on available funding. Before TMDLs are scheduled for Category 5B waters, the water quality standards will be reviewed to determine whether uses and criteria are appropriate and accurate. Category 5C waters require additional monitoring to better characterize the water quality conditions. This information will determine whether the water quality standard should be reviewed or a TMDL should be scheduled.

The consolidated report lists the status of streams, reservoirs, estuaries and near-shore waters in the Gulf of Mexico, as well as the agency's plans for dealing with existing water quality problems. Restoring the quality of water bodies to meet their designated uses is usually a long-term project, taking five years or more.

Category	Total Number of Waterbodies	Streams	Reservoirs	Estuaries	Ocean
5a	101	64	15	21	1 (3,879 sq. miles)
5b	35	31	4	0	0
5c	162	142	15	5	0
Total	298	237	34	26	1 (3,879 sq. miles)

Indicators of Problems

The TCEQ conducts regular monitoring and assessments of surface waters to determine which water bodies meet the standards for their designated uses—recreation, drinking water, general water uses, and/or support of aquatic life. The most common impairments found during water sampling are as follows:

Bacteria levels: Elevated concentrations of fecal coliform, *E. coli* and enterococci are signs that waste may have reached the waters from inadequately treated sewage, improperly managed farming operations, failing septic systems or pets in urban areas.

Dissolved oxygen: Aquatic life requires oxygen concentrations at a certain level to survive and thrive. The inability to support diverse, abundant aquatic life is an indication of poor water quality.

Dissolved solids: High levels of dissolved solids, such as chloride and sulfate, can cause water to be unusable—or simply too costly to treat—as a source for drinking water.

Metals: High concentrations of metals such as cadmium, mercury and lead threaten drinking water supplies and human health. Evidence of metals often shows up in fish tissue or in bottom sediments. Metals also can affect livestock and aquatic life.

Organics: Toxic substances from pesticides and industrial chemicals pose the same concern as metals. DDT, for example, was banned in the 1970s, but remains in the environment.

Nonpoint source pollution is a significant factor contributing to problems in Texas water bodies. Nonpoint source pollutants can be traced to causes such as fertilizer, pesticides, leaking oil from cars and trucks, and construction debris. This pollution is often carried into creeks and streams by runoff.

Patrick Roques of the TCEQ says the number of water bodies assigned to Category 5 demonstrates that "Texas has significant challenges in addressing nonpoint sources, as well as some localized contamination issues that will require lengthy recovery. Some are persistent, long-term contamination problems."

The TCEQ works with a number of partners to keep tabs on water quality around the state. The Texas Clean Rivers Program and federal, state, regional and local agencies collect and share relevant data.

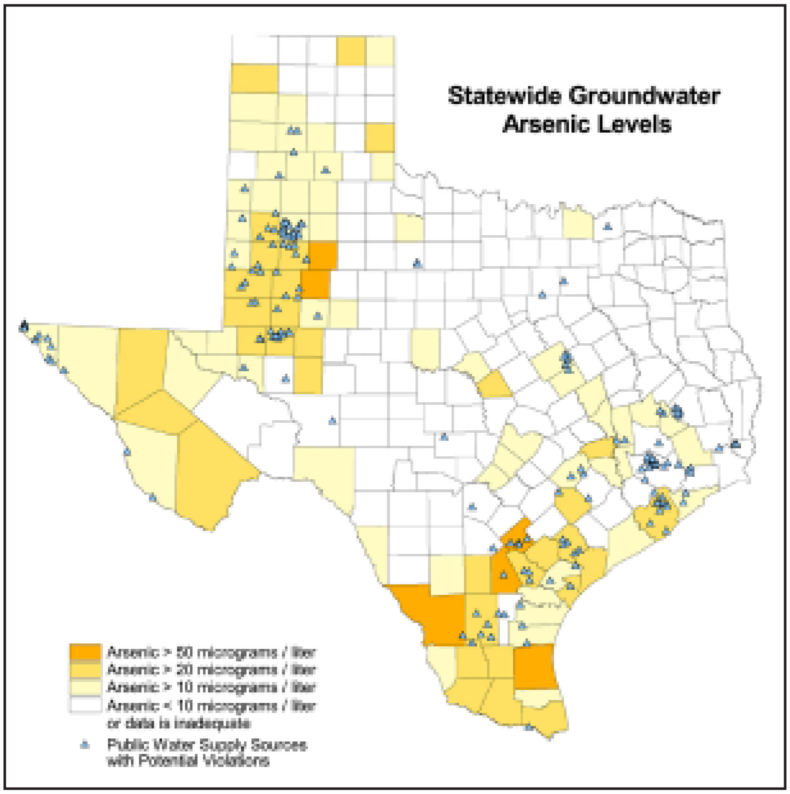
Addressing water quality in a state this size can be a daunting task, admits Roques, who heads up the agency's Surface Water Quality Monitoring Program. "It's a challenge, but we feel we're monitoring water bodies with the highest human use and representing the most important resources for drinking water, recreation and aquatic life," he said.

Technical information regarding TCEQ's TMDL process provided by Louanne Jones, information specialist, TCEQ.

For more information on impaired water bodies, visit http://www.tceq.state.tx.us/nav/eq/eq_water.html

Arsenic May be a Groundwater Concern in High Plains, Gulf Coast

by Ric Jensen



Homeowners and the public in the High Plains, Gulf Coast and other impacted areas will likely soon hear more about levels of arsenic in drinking water since environmental regulatory agencies have now implemented a more strict standard for this trace element.

Arsenic is a potentially toxic substance that, in large doses, leads to adverse health effects in humans, livestock and pets. In some cases, arsenic can migrate into drinking water from natural sources such as soils and rocks.

On the other hand, human activities such as pesticide production and management, livestock operations and industrial processes can also be sources of arsenic pollution. Arsenic was previously used to defoliate cotton, but it is no longer in widespread use.

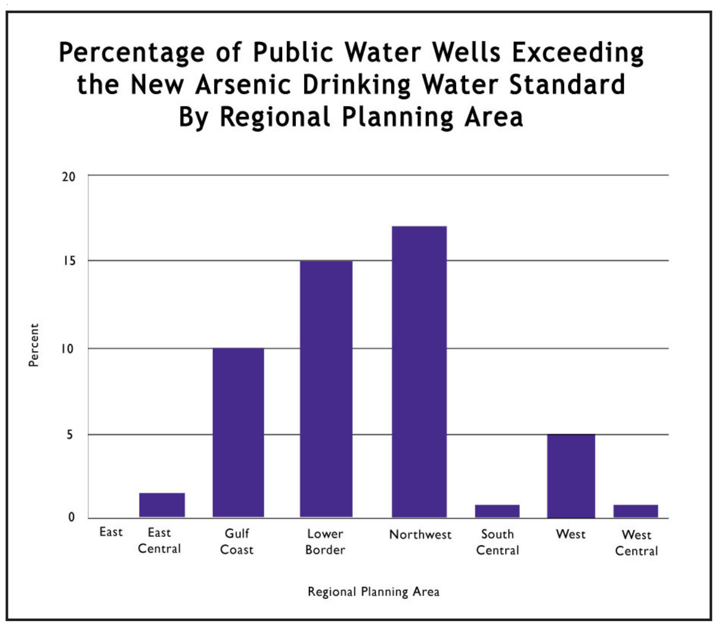
Until 2001, the U.S. Environmental Protection Agency and the Texas Commission on Environmental Quality enforced an allowable limit of 50 parts per billion (ppb) of arsenic in drinking water. While the 50 ppb standard is still being enforced, the agency is preparing water suppliers for a 10 ppb criterion that will be fully implemented by January 2006.

How widespread is the arsenic problem in Texas? The TCEQ estimates that roughly 8 percent of drinking water wells in Texas may exceed the 10 ppb standard. In practical terms, as many as 200 public water systems that rely on groundwater will have to reduce arsenic levels to meet the new standard. Roughly 5 percent of the state's population obtains its drinking water from these 200 systems.

"I am most concerned about home water wells in which water is not treated," said Richard Loeppert, a researcher in the Texas A&M University Soil and Crop Sciences Department. Dr. Loeppert has studied arsenic pollution in Bryan, Texas resulting from the management of cotton defoliants, as well as the naturally occurring arsenic contamination in Bangladesh. "Well owners might want to test their water just to be sure," said Loeppert. "Once they learn whether arsenic is a problem, there are treatment strategies to effectively manage it."

The U.S. Geological Survey (USGS) recently carried out extensive aquifer studies in Texas as part of the National Water-Quality Assessment (NAWQA). From 1998 to 2001, the USGS sampled 48 domestic wells in the Southern High Plains for a suite of potential contaminants, including arsenic, and 14 of those wells exceeded the new standard of 10 ppb. The study did not determine if the presence of arsenic was the result of natural conditions or human influences.

"The presence of arsenic in the Southern High Plains may be the result of natural conditions, but we need more studies to identify the extent of arsenic in soils and rocks to verify that theory," said Lynne Fahlquist, a USGS scientist who coordinated the High Plains NAWQA. "The USGS did not find evidence that human activities associated with cotton production may be the source of arsenic pollution in some of the shallow wells of the High Plains."



In the mid-1990s, the USGS examined groundwater quality in South Central Texas and again arsenic was present in some wells, but typically at levels well below the 10 ppb standard. At the same time arsenic is acknowledged as a water quality challenge, it should also be noted that researchers throughout Texas are working to learn more about this issue and develop solutions. Some of those are:

Bruce Herbert and Timothy Kramer
Texas A&M University Departments of Geology; Civil Engineering
Examining influence of uranium mining and natural conditions on arsenic levels in South Texas groundwater

Richard Loeppert
Texas A&M University Department of Soil and Crop Sciences
Developing efficient and effective methods to treat and remove arsenic from drinking water supplies

Jill Brandenberger
Texas A&M University - Corpus Christi
Evaluating groundwater conditions throughout the Lower Neches River Basin and Lake Corpus Christi

Paul Hudak
University of North Texas
Investigating extent to which cotton farming and other agricultural activities in the High Plains correlate to arsenic levels in the region's groundwater

Monty Dozier and George Gonzales
Texas Cooperative Extension
Screening water quality in 91 wells in the Lower Rio Grande Valley for arsenic, nitrate, bacteria and salinity. Average arsenic concentrations are 2 ppb and potential arsenic sources being investigated include dips used to treat cattle, agricultural activities and natural conditions

Pharmaceuticals

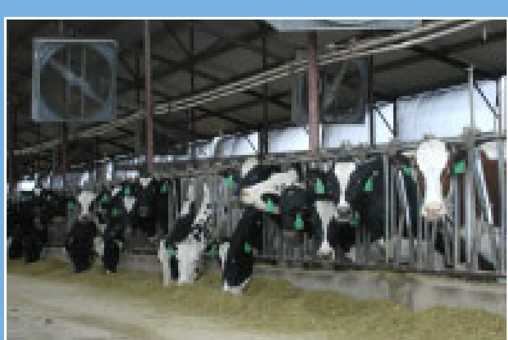
continued from page 3

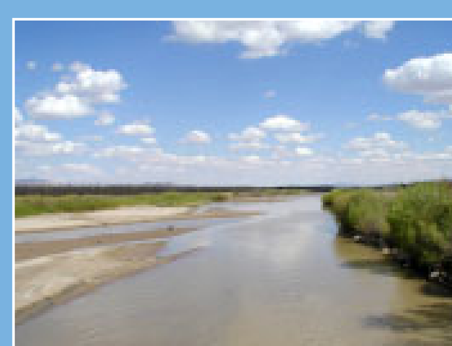
Determining the extent to which pharmaceuticals might be present in surface and ground waters of the El Paso region is the focus of studies at Texas Tech University. Researcher Audra Morse of the Civil Engineering Department are carrying out studies for El Paso Water Utility (EPWU) that investigate the extent to which estrogens, caffeine, antibiotics and other hormones and pharmaceuticals may be present in the Rio Grande River.

"This problem may be more acute in arid regions like West Texas where streams may only flow intermittently and may be effluent-dominated," Morse said. "These compounds are designed to cause physiological effects in humans that may result in similar changes to aquatic species in the environment." At the same time, Morse is also working with EPWU to study if highly treated wastewaters injected underground as a supplemental source of drinking water in the El Paso region might result in elevated concentrations of these chemicals in drinking water.

At Texas A&M University, graduate student Jeffrey Ullman is beginning a research project under the direction of researchers Saqib Mukhtar of the Biological and Agricultural Engineering Department and Scott Senseman of the Soil and Crop Sciences Department. The goal of this study is to learn more about the fate and transport of hormones and endocrine disruptors that might run off from concentrated animal feeding operations (CAFOs). "One of the things we hope to learn more about is whether hormones that originate in CAFOs are still active when they reach surface waters," Mukhtar said. "It is possible that these contaminants might be reduced by environmental processes before they reach rivers and streams."

Scientists do not yet know the extent to which pharmaceuticals, hormones and endocrine disrupting chemicals might be present in surface waters of Texas or whether these contaminants might be adversely affecting the environment. Still, national studies suggest the issue needs to be studied, in part to better understand if there might be ramifications for aquatic species and perhaps humans.





For more information, visit http://toxics.usgs.gov/regional/emc_sourcewater.html and http://www.epa.gov/nerlesd1/chemistry/ppcp/media.htm

Fecal Studies Get to the Point

Bacterial Source Tracking

by Kellie Potucek

Before a problem can be fixed, one has to know where it originates. This profound statement is the essence of Bacterial Source Tracking (BST). Also referred to as "fecal sourcing" or "fecal typing," BST is an evolving technology that seeks to accurately identify the contributing sources of bacteria in water, whether from various species of livestock, wildlife or humans. Through analysis of fecal bacteria, researchers hope to identify origins of bacteria contamination in order to improve water quality.

"Bacterial contamination of waters is a leading cause of surface water impairments in the U.S. and is considered a health risk," explains Post-Doctoral Research Associate Alexandria Graves of Texas A&M University. Nationwide, thousands of stream segments and tens of thousands of stream miles are in violation of water quality standards because of fecal bacteria. Regulatory agencies may ultimately use BST to investigate and rectify such violations.

Fecal contamination is generally categorized as coming from human, livestock or wildlife sources. The difficulty in pinpointing a source lies in the dynamic nature of fecal or intestinal microbial contamination. "The large differences in fecal wastes produced by various animals, and the spatial and temporal variablility of where the waste was excreted in any given watershed make determining which sources (and in what proportions) enter surface and ground waters a daunting problem," said Graves. Additionally, weather, land use and land cover changes in landscape and water environments affect the dispersion and transformation of fecal bacteria. These challenges are addressed by numerous scientific measurement techniques identified as BST.

At least seven BST methods are currently in development and can be classified as either molecular or biochemical. These methods are highlighted in the chart. Molecular techniques, also known as "DNA fingerprinting," rely on the unique pattern of genes found in various strains of fecal-coliform bacteria. Biochemical BST is based on the analysis of type and quantity of a protein, enzyme or other biochemical substance actively produced by an organism's genes.

Because BST is an emerging technology, the advantages and disadvantages of its various methods have only begun to be realized. Molecular methods seem to produce highly precise identification, but they are also expensive and time consuming. Conversely, biochemical methods are cheaper and faster, but results are not as precise as molecular techniques. Graves explains, "As research is completed over the next few years, it seems likely that some combination of BST methods will be needed to provide the most economical, accurate and reliable source identification."

Seven methods under development in Bacterial Source Tracking (BST)

Molecular Methods (all are referred to as "fingerprinting")

Restriction analysis—Based on digesting a cell's DNA with specialized enzymes, called restriction enzymes, to produce a unique pattern.

Ribotyping—Based on finding that portion of a cell's DNA that is highly protected from mutations; the portion is then isolated and analyzed.

PCR methods—Based on amplifying small fragments of DNA many times by Polymerase Chain Reaction (PCR); these fragments are then compared to find unique segments.

Biochemical Methods

Antibiotic resistance analysis—Based on differences in resistance to antibiotics shown by different strains of fecal bacteria.

Fatty acid analysis—Based on the types and quantities of fatty acids in the cell walls of bacteria.

Nutritional patterns—Based on differences among bacteria in their use of a wide range of carbon and nitrogen sources for growth.

Fecal-bacteria ratios—Based on the ratios (presence and numbers) of many different types of stomach and intestinal bacteria, not just fecal coliform bacteria.

Brackish Groundwater Issues in Texas

by Ric Jensen

Much of Texas' groundwater is adversely affected by varying levels of salinity, which is measured by the concentrations of salts or total dissolved solids (TDS). Although TDS can be influenced by substances not related to salinity, it is typically used to determine salinity levels for most purposes.

Varying levels of salinity are defined as "brackish" water, having a TDS measurement of 1,000 to 10,000 parts per million (ppm) and "brine" with concentrations of greater than 10,000 ppm.

Although slightly saline groundwater (1,000 to 3,000 ppm TDS) can be used for crop irrigation and livestock watering, the drinking water standard for TDS, set by the Texas Commission on Environmental Quality, is 1,000 ppm.

According to the Texas Water Development Board (TWDB), brackish groundwater is present in most of Texas' minor and major aquifers, resulting in a total volume of brackish groundwater of more than 2.5 billion acre-feet. An acre-foot is the volume of water needed to cover an acre of land at a depth of one foot (gallon).

In general, areas containing significant brackish groundwater resources can be found in West Texas, North Central Texas, Central Texas, and the Southern Gulf Coast. Major aquifers that contain brackish groundwater include the Ogallala, Trinity, Carrizo-Wilcox, Edwards, Edwards-Trinity, Gulf Coast, Seymour, Hueco and Mesilla Bolsons.

Efforts to capture, treat and reuse brackish groundwater are already underway in Texas. El Paso, for example, is now developing a desalination plant to treat brackish groundwater from the Hueco Bolson aquifer. Additionally, Brownsville has successfully developed a water supply source from brackish groundwater of the Gulf Coast Aquifer.

Several experts suggest it may now be economically feasible to recover, treat and reuse brackish and saline groundwater because advances in technology are making this process more efficient and less costly.

Texas Water Resources

Texas Water Resources Institute
make every drop count

Texas Agricultural Experiment Station
THE TEXAS A&M UNIVERSITY SYSTEM

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