New Ways To Clean Up Water and Use It Again

PEGGY GREB (D1316-1)

Soil scientist Matias Vanotti monitors conditions in a bioreactor that uses immobilized bacteria to remove nitrates from agricultural effluents.

In 2006, farmers in North and South Carolina earned some $10 billion from crops and livestock, but it wasn't easy money. Like elsewhere in the country, livestock and crop producers in this region struggle with managing agricultural pollutants that can affect the quality of surface water and groundwater.

Excess rainfall can also be a problem—and so can damaging droughts. These droughts, which can start as short dry spells, are exacerbated by the region's sandy soils, which have a limited capacity for holding water.

Agricultural engineer Ken Stone and soil scientist Patrick Hunt joined colleagues at the ARS Coastal Plains Soil, Water, and Plant Research Center in Florence, South Carolina, to make the job a little bit easier. They're finding ways to clean up nitrogen that escapes to drainage water and ways to use pretreated swine wastewater for crop irrigation.

Digging for New Solutions

As part of this effort, the scientists tackled a significant downside of crop production—the excess nitrate sometimes carried away by field drainage. This nitrate comes mainly from nitrogen fertilizers that are not taken up by crops.

Tile drains installed under crop fields are essential to crop production in much of North America. But they can also discharge large amounts of nitrate into bodies of water such as the Gulf of Mexico and the Chesapeake Bay. This nitrate can lead to development of oxygen-deficient "dead zones" in the larger water bodies, a condition called "hypoxia." So Hunt and soil scientist Matias Vanotti began to look for a denitrifying process that could take place in subsurface drains before the nitrate-laced runoff reached sensitive aquatic ecosystems downstream.

The team obtained denitrifying bacteria from soil samples collected at a nearby overland flow treatment site and cultured them in the lab. Then they encapsulated the bacteria in polymer gels and verified their denitrification rates. They called the final product "immobilized denitrification sludge," or IDS.

Hunt and Stone then devised a bioreactor by placing the IDS into a small reactor cylinder. For about 6 weeks they pumped a test solution containing nitrate through the bioreactor and confirmed that the device effectively removed nitrate from the solution.

The team then tested a bioreactor in the field, where nitrate concentrations in runoff averaged 7.8 milligrams per liter. (The federal standard for nitrate in drinking water is 10 milligrams per liter.) They sampled inflow and outflow nitrate concentrations in the runoff at 4-hour intervals for 36 days.

Hunt and environmental engineer Kyoung Ro determined that the hydraulic retention time (HRT)—how long the field drainage water remained in the bioreactor—was crucial in the denitrification process. With a 1-hour HRT, 50 percent of the nitrogen was removed from the runoff. When the HRT was increased to more than 8 hours, the nitrate-removal efficiency approached 100 percent.

Based on these results, the team concluded that the daily nitrate-removal rate of a 1-cubic-meter bioreactor would be about 94 grams per square meter of nitrate from field runoff. This is significantly higher than removal rates reported for in-stream wetlands, treatment wetlands, or wood-based bioreactors.

“This means that the IDS bioreactors could treat nitrate hot spots and moderate the impact of storm flows,” Stone says. “But we need to conduct a full-size test of this process to see how well it works during prolonged storm patterns—when drainage volumes increase—and during extreme droughts.”

“We also need to see how IDS reactors can be integrated effectively with other agricultural practices—like good nutrient-management plans, controlled drainage, treatment wetlands, and passive carbonaceous reactors,” Hunt adds.

Every Drop Counts

A climatologist will say that the Carolinas receive an average precipitation of 4 inches per month. But farmers here know that there are months when almost no rain falls.

Livestock wastewater is typically used to irrigate crops, but its high nutrient content limits its use. Moreover, spray irrigation enhances the emission of ammonia and other volatile organic compounds present in the wastewater.

Stone, Hunt, and Vanotti wanted to see whether subsurface drip irrigation (SDI) with pretreated swine wastewater could eliminate emissions and increase the effectiveness of irrigation. They conducted a 2-year study of SDI that compared yields of bermudagrass hay irrigated with wastewater and hay irrigated with well water and amended with commercial fertilizer. The wastewater was pretreated to remove concentrations of nitrogen and phosphorus.

When the SDI study was over, the team assessed hay yield, hay biomass, soil nutrients, and soil-water nutrients. They found that SDI crop yields were higher for the bermudagrass that had been irrigated with the pretreated wastewater.

The scientists also found that yields of bermudagrass hay did not vary significantly when the crops were irrigated with wastewater levels that replenished only 75 percent of the water lost to evapotranspiration. This suggests that wastewater SDI can be effective at lower application rates, which would help conserve water supplies. It would also reduce the amount of water draining through the soil, which would lessen the opportunity for plant nutrients to be leached below the root zone.

“We’ve found that by irrigating with treated swine wastewater, we can use less water than traditionally required. Since water is a precious commodity, this finding is extremely important,” says Vanotti.

All these results suggest that SDI with treated swine wastewater provides forage crops with both water and fertilization. The benefits can equal—and even sometimes exceed—those of using commercial fertilizer.

“In the late 1990s, the swine population in this area increased from around 2 million animals to around 10 million,” Hunt says. “When we find ways to recycle the byproducts from this intensive livestock production to replenish scarce water supplies and boost crop yields, everyone benefits.”—By **Ann Perry,** ARS.

This research is part of Water Availability and Watershed Management, an ARS national program (#211) described on the World Wide Web at www.nps.ars.usda.gov.

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PEGGY GREB (D1315-1)

In Florence, South Carolina, agricultural engineers Kenneth Stone (left) and Joseph Millen collect bermudagrass hay for forage quality and nutrient analyses. They compared yields of hay grown with treated wastewater to those grown with commercial fertilizers.

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In Duplin County, North Carolina, this full-scale wastewater-treatment system provided treated swine wastewater for the drip-irrigation study.