Long-Term Treatment of Industrial Discharge for Metals with Constructed Wetlands

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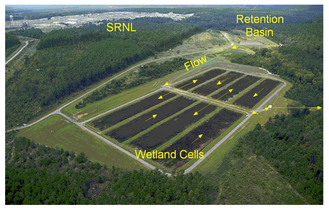
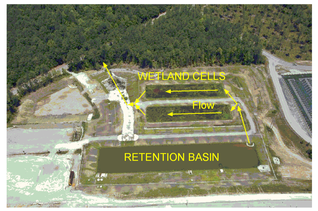
The Savannah River Site (SRS) is a large Department of Energy facility (80,267 hectares) located along the Savannah River in west central South Carolina. The SRS has numerous production and industrialized areas that produce industrial waste water discharges. These discharges are regulated by the state of South Carolina, and are subject to discharge limits for numerous possible contaminants. The Savannah River National Laboratory implemented a constructed wetland treatment system in 2000 to treat industrial discharge and stormwater from the Savannah River Laboratory area. The industrial discharge average volume is 800,000 gallons per day (3,030 m^3) with elevated toxicity and metals (copper, zinc and mercury) constituents. Several options were evaluated to treat this discharge ranging from source removal, to collection and transport to an existing wastewater treatment facility, to installing an ion exchange treatment facility, to building a constructed wetland treatment system. The Constructed Wetland Treatment System (CWTS) was identified based on performance, capital and continuing cost, and schedule. A key factor for this natural system approach was the long-term binding capacity of heavy metals (especially copper, lead, and zinc) in the organic matter and sediments through biogeochemical cycling and storage. Based on economic and feasibility studies, a constructed wetland treatment system was pursued as the solution to water quality improvement for the A-01 outfall of the Savannah River National Laboratory. The design required that the wetland treat the average discharge volume of 800,000 gallons (3,030 m^3) per day, and be able to handle 22 million gallons (83,280 m^3) of stormwater runoff in a 24 hour period. The design allowed all water flow within the system to be driven by gravity so no pumps were required.

The CWTS for A-01 outfall is composed of eight 0.405 hectare (one-acre) wetland cells connected in pairs as treatment units, with a total surface area of the wetland cells of 3.25 hectares. They were planted with giant bulrush to provide continuous organic matter input, and provide resistance to water flow across the cell. A retention basin was designed to hold stormwater flow prior to entry into the wetlands and to allow control of water flow into the treatment system. The system became operational in October of 2000 and was the first wetland treatment system permitted by South Carolina DHEC.

Because of the exceptional performance of the A-01 CTWS, the same strategy was used to improve water quality of the H-02 outfall that receives discharge and stormwater from the Tritium Area of SRS. The primary contaminates in this outfall were also copper and zinc. The design for this second system required that the wetland treat the average discharge volume of 110,000 gallons (415 m^3) per day, and be able to handle 2.56 million gallons (9,690 m^3) of stormwater runoff in a 24 hour period. This allowed the building of a system much smaller than the A-01 CWTS. Additionally, because wetland facilities increase the dissolved organic carbon in the effluent as part of the normal wetland function, the bioavailability of metals exiting from the wetlands is also greatly reduced to biological receptor species. Because of this, the discharge limits for individual outfalls can be negotiated with the regulators based on water effects ratios and biotic ligand models that have been approved. The system became operational in July 2007.

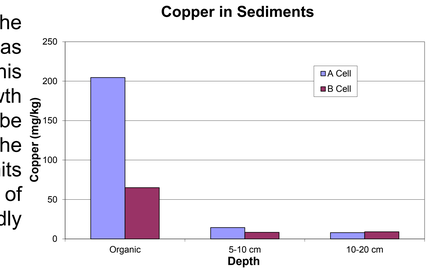


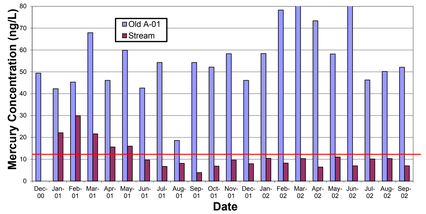
A-01 Wetland System



H-02 Wetland System

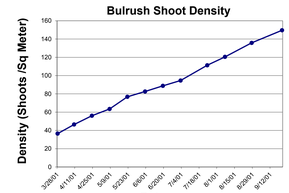
The treatment systems were designed to reduce copper concentration in the effluent and to allow the effluent to pass toxicity tests. Copper removal has been excellent since water flow through the treatment systems began, and this improved with the maturation of the vegetation during the first season of growth of each system. Water sampled at the inflow to the CWTS continued to be routinely above the permit limit. After passage through the treatment cells, the copper concentration is well below permit limits, and often below detection limits of the test procedure (5 µg/L). Sediment samples after the first year of operation indicated that copper was being bound in the sediments very rapidly after entering the treatment system.



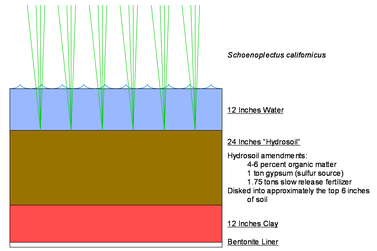


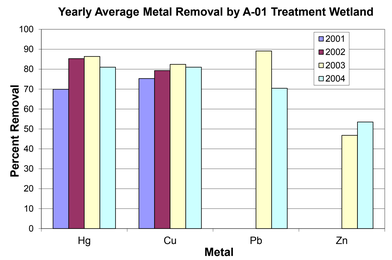
Mercury content in the water of the A-01 outfall was also monitored using the ultra-low detection methodology that is now available. Because the design of the system encourages a low redox status of the sediments in the treatment cell, it was anticipated that mercury would also be removed from the water column. Mercury removal improved with maturation of the vegetation and the sediments, and averaged greater than 80% removal of total mercury during the second year of operation.

Vegetation development within the treatment wetland cells has been excellent. Most cells were near optimal maximum densities of bulrush shoots reported for natural systems. Growth rates of the shoots have been very impressive, averaging over 6 centimeters per day during the maximum elongation phase of growth. Biomass production has also been excellent and provides the organic matter that the system utilizes for continuing functionality.



Typical Cell Cross Section





The long term performance of these wetland treatment systems in the Southeast US has been exceptional, both in terms of the removal efficiency of metals from the influent water and in terms of the low cost of operation. Costs for maintenance and operation of the systems are minimal, consisting primarily of ensuring that the pipes are not clogged and that water is flowing through the system. The treatment cost per thousand gallons is many times less than conventional wastewater treatment facilities. The "design life" of the facility is 20 years, but the actual performance life will be considerably longer. No hazardous waste is being created in the wetland cells due to the low concentrations of metals that are being accumulated and sequestered in the organic sediments and the soil profile.

Current research is focused on assessing the ability of this wetland treatment system to remove other contaminants, organic matter decomposition and accretion, and evaluating the fate and stability of metals once bound in the sediments.

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