USE OF ENGINEERED WETLANDS TO PHYTOREMEDIATE EXPLOSIVES CONTAMINATED SURFACE WATER AT THE IOWA ARMY AMMUNITION PLANT, MIDDLETOWN, IOWA

Authors

Jackson H. Kiker - ECC
Kpfuentes@aol.com
Phone: (401) 736-4032

Donald D. Moses – USACE – Omaha District
donald.d.moses@usace.army.mil
Phone: (402) 221-3077 Fax: (402) 221-4571

Steve Larson – USACE – WES
Steven.l.larson@wes02.usace.army.mil
Phone: (601) 634-3431

Randy Sellers – USACE – Omaha District
Randy.p.sellers@usace.army.mil
Phone: (402) 221-3054 Fax: (402) 221-4886

Introduction Most Department of Defense installations have environmental sites with contaminated ground and surface water including streams and impoundments. Traditionally, contaminated water has been remediated using industrial treatment processes such as "pump and treat" systems. Alternatively, phytoremediation, which is a rapidly developing technology, can be used to treat contaminated water and sediments. Phytoremediation is the use of plants to uptake and degrade contaminants. Phytoremediation works in synergy with other natural processes that degrade contaminants including photolysis and indigenous soil microbes. To take advantage of these natural processes, two engineered wetlands have been constructed at the Iowa Army Ammunition Plant (IAAAP) in order to phytoremediate explosives contaminated surface water.

The construction of the engineered wetlands at the IAAAP is the first full-scale implementation of a phytoremediation system designed to treat explosives contaminated surface water. The wetlands successfully remediated RDX in surface water from approximately 800 ppb to non-detect (<.25 ppb) levels. Explosives levels were monitored in the surface water, sediments, underlying soils and in the plant tissues. The wetlands are functioning successfully without posing an ecological threat. The wetlands add aesthetic and ecological value to the environment. The wetlands are less costly and do not require energy to operate.

Project Description The Iowa Army Ammunition Plant's (IAAAP) operations consist of loading, assembling, and packing (LAP) ammunition items, including projectiles, mortar rounds, warheads, demolition charges, anti-tank mines, and anti-personnel mines. The LAP operations at IAAAP have resulted in the discharge of wastewater containing explosive by-products to surface streams and impoundments. The Line 1 Impoundment and Line 800 Pink Water Lagoon were considered to be the greatest sources of explosives contamination at the IAAAP.

Both sites were remediated in 1997 by excavating explosives contaminated soils and relocating the material to engineered landfills or temporary stockpiles. As an alternative to backfilling the excavations, both sites were reclaimed as engineered wetlands. Phytoremediation was implemented at both sites to treat residual contamination and to preserve the option of using the wetlands in the future for the treatment of contaminated groundwater. In order to establish wetland vegetation, the excavated areas were lined with sediment from several local sources.

The water in both wetlands originate from both surface runoff and groundwater infiltration.

Supporting Studies Prior to establishing the wetlands, a site-specific study, "Screening of Aquatic and Wetland Plant Species for Phytoremediation of Explosives-Contaminated Groundwater from the Iowa Army Ammunition Plant" was conducted by the U.S. Army Corps of Engineers Waterways Experiment Station (WES). Submergent and emergent wetland plant species native to the IAAAP were evaluated for their ability to degrade aqueous explosives found in IAAAP groundwater. Submersed plants studied were American pondweed and coontail. Emergent plants studied were water-plantain, arrowhead, fox sedge, wool-grass, spikerush, reed canary grass and narrowleaf cattail. Explosives-contaminated groundwater, with RDX and TNT at 12,785 ppb and 682 ppb respectively, was obtained from two monitoring wells adjacent to the Line 800 Lagoon. Hydroponic trials were conducted over a 10-day trial period. At 25^{o} C, plant incubations achieved 94 to 100 percent TNT removal, while groundwater, sediment and autoclaved sediment controls ranged from 62 to 85 percent. TNT uptake in the plant tissues were near the detection level of 0.1 $\mu g\ L^{-1}$ in the extract indicating the TNT did not bio-accumulate. At 25^{o}C, plant incubations achieved an average removal for RDX less than 15%. The plant removal rate was comparable to the groundwater (11%), sediment (21%) and autoclaved sediment (25%) controls. RDX concentrations in the plants were high (averaging 200 $\mu g\ g\ DW^{-1}$ or ppm) indicating translocation. The short period of the RDX trials did not allow for a conclusion that RDX was permanently bio-accumulated or that the RDX accumulations were transient, because of the plants slower rate of RDX metabolism compared to that of TNT. Subsequent WES radiolabelled studies have conclusively shown that RDX can be metabolized.

Implementation of the Engineered Wetlands Results of the WES study, discussed above, demonstrated that quick phytoremediation of TNT contaminated water was feasible whereas the findings for RDX were inconclusive. However, the wetlands were constructed with the understanding that removal mechanisms associated with a full-scale field implementation would be more robust and improve as compared to the artificial laboratory environment. A boost in enzymatic degradation was foreseen, because plants that naturally established have greater density and diversity as compared to the limited species assessed in the laboratory. Plant species selection was based upon an effort to create low maintenance, self-sustaining, and long-term success for the life of the wetlands. For this reason, plants and seedbank were selected from on-site areas rather than purchasing plants or seed from commercial sources. The wetlands were monitored to demonstrate the effectiveness of phytoremediation and to assure the process did not pose an ecological risk. Surface water, sediments, and plant tissues were monitored for explosives. Data was collected during the 1998, 1999, and 2000 growing seasons.

Plant Inventory and Explosives Uptake A vigorous growth of diverse upland, fringe and wetland plants has naturally established from seedbank in both the Line 800 Lagoon and in the Line 1 Impoundment. Approximately 50 species were observed at each wetland. Rice Cutgrass (*Lersia oryzoides*), Smartweed (*Polygonum punctatum*), and Reed canarygrass (*Phalaris arundinacea*) are the dominant fringe species. Pondweed (*Potemogeton sp.*), Water Plantain (*Alisma subcordatum*), Arrowhead (*Sagittaria sp.*), Hornwart (*Ceratophylum demersum*), and Stonewart (*Chara*), are the dominant emergent species in both ponds.

During the 1999 growing season plant tissue samples were obtained in June, (at the beginning of the growing season), in August (during the mid-point of the growing season), and in late September (towards the end of the growing season). Plants were sampled again in August during the 2000 growing season. Split samples of plant tissue samples were collected and sent to WES and the University of Iowa for explosive analysis by HPLC method 8330 with a modified sample preparation technique. Nearly all of the above mentioned species were analyzed in each sampling effort. All three sampling rounds from both Line 1 and Line 800 yielded non-detects for explosives in the plant tissues in 1999. In the 2000 event, both Line 1 and Line 800 plants were found to contain very little, if any, explosives related compounds.

Surface Water Quality Composite surface water samples are obtained monthly at both wetlands. Surface water quality was analyzed by SW-846 Method 8330 for the entire suite of explosives. RDX is the primary contaminant found in the surface water at both wetlands. The first surface water quality samples were obtained in January of 1998 when the wetlands had first filled with water and had little vegetation established. The initial RDX levels were the highest recorded being 260 ppb at the Line 800 Lagoon and 778 ppb at the Line 1 Impoundment respectively. These values far exceed the 2 ppb EPA Health Advisory Lifetime level for RDX which is used as a discharge standard. The initial elevated RDX levels were attributed to the fresh wetting of the recently disturbed soils containing residual contamination of RDX in the soil at 1.3 ppm and TNT at 47.6 ppm. At the IAAAP, RDX is not strongly bound to soil and readily partitions from the contaminated soil media into surface and groundwater. RDX levels decreased below the initial contaminant levels of 260 ppb (Line 800), and 778 ppb (Line 1), to below the 2.0 ppb discharge value during the initial growing season in 1998. Subsequently, RDX rebounded in the winter months to approximately 30 ppb. During the following summers of 1999 and 2000, rebound levels dropped to or near non-detect levels.

Levels of RDX in surface water at both Lines 1 and 800, even at rebound levels, do not appear to pose an ecological risk. This is based upon effects levels shown by Talmage et. al. in, *Nitroaromatic Munition Compounds: Environmental Effects and Screening Values*, 1999, Journal Rev. Environ. Contam. Toxicol. 161:1-156. Water quality criteria, secondary chronic values, presented in that report are placed at 190 ppb for RDX.

Conclusion During the first three years of operation, the phytoremediation wetlands at both the Line 1 Impoundment and the Line 800 Lagoon have been successful in reducing RDX levels in the surface water to below the discharge requirement of 2 ppb. Although the RDX levels have increased in the winter, the levels have been far below values indicated as posing potential ecological risk. It is recognized that other natural processes aided the reduction of explosives in the surface water besides phytoremediation. The explosives removal mechanisms, while not fully established are most likely a synergistic combination of photolysis, plants, and waterborne and soil microorganisms.