MONITORING THE EFFECTIVENESS OF PHYTOREMEDIATION AND HYDROGEOLOGIC RESPONSE AT AN AGRICULTURAL CHEMICAL FACILITY

WRI#: R/UW-REM-009, GCC#:03-REM-06

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July 1, 2002 – June 30, 2004

Background - Phytoremediation offers the prospect of using biotechnology to degrade or sequester contaminants from soil and groundwater, and/or slow the movement of shallow groundwater. Sequestration of heavy metals and degradation of petroleum hydrocarbons and volatile organic compounds is well documented; however, the fate of many pesticides is unclear. If groundwater movement can be slowed, possibly so will the movement of contaminants off-site, and therefore, a greater likelihood they will be degraded by biotic or abiotic processes, or be sequestered by plants.

The study site, located near Bancroft, Wisconsin, has a history of soil and groundwater degradation. Dinoseb (2, sec-butyl-4,6-dinitrophenol) is the primary contaminant of concern and this soil is unacceptable for conventional landfill disposal or landspreading. Sandy soil, shallow groundwater, and other factors make this a prime site to study the effects of phytoremediation. In June 2000, a mixture of 834 hybrid poplars, willows, and cottonwoods were planted in an effort to degrade and/or retard the movement of pesticides.

Objectives - The objectives of this research were:

1) Assess mortality and biomass production of the established trees at the site as they begin tapping into the capillary fringe of groundwater.
2) Correlate hydrologic response to transpiration rates at various times through the project duration (both daily and seasonal changes). Calculate radius of influence based on water table observations and correlate the results with a capture-zone model.
3) Determine changes in groundwater contaminant profile through the plots. Perform biannual testing on select monitoring wells (12 from the current project and three from the ACCP). Analyze a total of 32 samples per year on selected wells and piezometers. Install three to four piezometers with 2-foot screens to help assess the vertical extent of contamination.

Methods - Mortality is assessed in the fall by visual inspection of the tree and evidence of viable leaves or leaf buds. Occasionally, determination of a viable tree is difficult as they may appear dead in the fall (as evident by a dried main stem, lack of leaves and buds) then resprout from the base the following spring.

Biomass is estimated through direct measurement of trunk diameter and height as recommended by U.S. Forest Service North Central Experimental Station. The equation for this estimation is d^2*h where d = diameter breast height and h = total tree height.

Hydrologic response is monitored with the use of groundwater elevation dataloggers (Aquarod – Sequoia Scientific) in three areas of the property. Elevation is logged once every 30 minutes with 1 mm of

accuracy. Transpiration is determined with the use of thermal dissipation probes (Dynamax, Inc.). These probes are inserted into the tree and sap velocity is determined as first proposed by Granier. Volume of sap is determined and assumed to be equal to water transpired. Transpiration is correlated to weather station (Davis Instruments) data and groundwater elevation.

Groundwater modeling was performed using WELFLO and Visual MODFLOW. Hydrogeologic conditions such as hydraulic conductivity, specific yield and saturated thickness were determined in previous studies. WELFLO uses analytical equations to predict drawdown near pumping wells. Visual MODFLOW is a numeric model used to predict groundwater contours in 2 or 3 dimensions.

Three monitoring well nests with 1-foot screens were replaced with 5-foot well screens. Four piezometers were installed at select points in the site to determine vertical extent of contamination. Groundwater samples were analyzed by EPA Method 8270 which utilizes gas chromatography/mass spectrometry.

Results and discussion - Dinoseb concentrations in groundwater continue to fluctuate widely. Slugs of dissolved contaminants are believed to be released during changing water table elevations and large rainfall events. The steady drop in groundwater elevation throughout the summers of 2003 and 2004 is believed to be the result of extensive pumping from high capacity wells and groundwater discharge to drainage ditches in the area. Sharp rises are associated with rainfall events and correlate with rainfall data collected at the site.

Diurnal fluctuations were observed to varying degrees beginning in July 2002 and throughout 2003, but were not observed in 2004. The maximum diurnal fluctuation observed was 10 mm. Diurnal fluctuations correlate with sap flow and evapotranspiration (as determined from weather station data), suggesting the diurnal fluctuations are the result of the trees extracting groundwater. Tree sap flow is affected by humidity, solar radiation, temperature and wind. Thermal dissipation probes determined that seven to 28 liters of groundwater per day are being transpired by each of the hybrid poplars during the time period measured (Sept. 30-Oct. 10). Assuming an average sap flow of 10 liters per day (lpd), 650 trees will transpire 6,500 liters per day, or 4.5 liters per minute, of groundwater removal. Subsequent measurements in the summer of 2004 have determined up to 100 liters per day with an average within 16 measured trees of 50 lpd.

Within the hydrogeologic assumptions made, WELFLO predicts that the drawdown observed with the AquaRods could be due to trees pumping at the transpiration rate observed. The use of MODFLOW showed only a very slight effect in the water table contours near the phytoremediation plot, which suggests that the trees are not capturing the groundwater that flows beneath the plot.

Conclusions - Fluctuations in groundwater contaminant concentrations indicate a source of dinoseb in the upgradient zone or possibly in the zone where containers were excavated. This makes it difficult to assess the impact hybrid poplars have on degradation of the contaminant. A separate study will evaluate tree tissue to determine the presence of dinoseb and dinoseb metabolites. It is evident that the trees are utilizing groundwater, and it is expected that retardation of groundwater flow will require more time.

Groundwater modeling portrays that the effect of the trees on groundwater flow becomes significant once the rate of evapotranspiration is increased by a factor of 10, which is expected in another two to three years.

Key words - dinoseb, phytoremediation, poplars, groundwater

Funding - Water Resources Institute, University of Wisconsin, McIntire-Stennis Cooperative Forestry Research Program.