Long-term performance of a pump and treat system at a wood treating site

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A wood treating facility in South Mississippi was the site of a twelve year, pump and treat remediation. Two sixty-five thousand liter batch reactors treated approximately 250,000 liters of creosote and penta contaminated groundwater per day. Four liters of penta and creosote degrading bacterial culture and 5 kg of triple thirteen fertilizer were added to the reactors on a weekly basis. The approximate residence time in reactors was 12 hours. Samples were taken on bi-weekly basis for Total Suspended Solids (TSS), selected priority pollutant creosote constituents/polycyclic aromatic hydrocarbons(PAHs), Penta and Tetrachlorohenol (PCP&TCP), Biological Oxygen Demand (BOD), and microbial counts. Reduction of PAHs, PCP/TCP, BOD, and TSS were 97%, 44%, 61%, and 54% respectively; viable bacterial populations over (700,000 colonies/mL) were present in effluent samples during a twelve year period.

Key Words: Bioremediation, Pump and Treat, Groundwater

Introduction

Contaminated groundwater has been found in all fifty states. Some of this water is contaminated with chlorinated organic pollutants such as pentachlorophenol (PCP) and polycyclic aromatic hydrocarbons (PAHs). The wood treating industry in Mississippi has been in operation for over one hundred years. Groundwater contamination by these compounds has been the result of leaching of these wood preservatives from soil at waste disposal sites into groundwater reserves.

Bioremediation is the biological treatment of contaminated soil and groundwater. This technology involves the use of microorganisms which can degrade the contaminating compounds in both soil and water. Bioremediation requires an understanding of microbiological processes relative to biodegradation of the target contaminants as well as the contaminants' physical and chemical effects on these microbial processes. Often these systems utilize aerobic metabolism which require the addition of oxygen, usually as air, and inorganic nitrogen and phosphorus.

Several methods are available to remove organic pollutants from groundwater (Borow, 1989; CAA Bioremediation Systems, 1988; Campbell et al., 1989; Heyse et al., 1986; Looney et al., 1992; Taddeo et al., 1989; TeKroney and Ahlert, 1992; Yare et al., 1987; Yare et al., 1989). Two of the most common methods are filtration and biological treatment. Both of these methods are effective in certain situations for groundwater cleanup of organic contaminants. Filtration involves the pumping of groundwater through carbon filters to remove contaminating organics. The cost for filtration of groundwater containing wood treating chemicals averages $1.25-$5.25 per 1000 gallons depending on influent concentration and the type of carbon used. This method is labor intensive and the spent carbon used for filtration has to be disposed of in ways other than incineration. This only relocates the contaminants. Biological treatment (pump and treat) involves pumping the contaminated water into bioreactors where cleanup is carried out by means of microorganisms at a cost of $1.00 per 1000 gallons. Both bacteria and fungi have been shown to be important in the bioremediation processes (Borazjani et al. 2005).

This paper presents only analytical and biological data collected during twelve years (1990-2001) and will not compare these results with other ex-situ or in-situ bioremediation. The only comparative evaluation made is with activated carbon because it was used before pump and treat system installation.

Materials and Methods

A suitable site was selected at a south Mississippi location where creosote and PCP were present in both groundwater and subsoil. The facility had been in operation since the early 1970s. The site had three open lagoons containing either pentachlorophenol,

pentachlorophenol in a heavy oil, or creosote. The open lagoon practices resulted in groundwater contamination in this 100 acre facility. In the late 1980s open lagoons were decontaminated by removing penta and creosote sludges and as scraping the residual contaminated soils. The site geology is McLaurin series and consists of deep, well drained, moderately permeable soil which occurs on ridge tops and upper slopes of ridges dividing major streams. Creosote and pentachlorophenol contaminants in open lagoons migrated downward and laterally following preferential pathways and eventually contaminating groundwater. Contaminated groundwater was pumped from five contaminated wells into two sixty-five thousand litter batch reactors. Approximately 250,000 litters of creosote and pentachlorophenol contaminated groundwater was treated per day. The approximate contaminated groundwater residence time in reactors was 12 hours. Reactors and a 300,000 liter clarifier were placed outdoors on a concrete platform. Samples were taken bi-weekly for Total Suspended Solids (TSS), selected creosote constituents (benzo (b) fluoranthene, benzo (k) fluoranthene, chrysene, fluoranthene, naphthalene, and phenanthrene), penta and tetrachlorophenol (PCP/TCP), Biological Oxygen Demand (BOD), and microbial counts.

Four litters of bacterial culture (Arthrobacter sp.), previously isolated and known to efficiently degrade PCP and PAHs (Walker, 1992) and 5 Kg of "13-13-13" fertilizer were added to reactors on a weekly basis. Two air pumps and metal agitators provided oxygen and mixing for each reactor with pH ranging from 5.90 to 6.70 .

EPA Method 3520 was used for extraction of groundwater (US EPA, 1986). PAHs and PCP were analyzed using EPA Methods 8100 and 8140, respectively (US EPA, 1986). BOD and TSS were determined by the EPA methods 405.1 and 106.2 respectively (Clesceri et al, 1989)

Viable plate counts were performed in order to assess the rate of microbial reproduction and to determine the numbers of microorganisms present. In this procedure, serial dilutions were plated onto a suitable solid growth medium using the spread plate technique. The culture medium for bacteria counts was prepared and then autoclaved for 20 minutes at 15 psi and 120° C. Each plate was inoculated with 0.5 ml of the diluted groundwater sample. The agar plates were then incubated at 28° C for 24 – 48 hours. The concentration of bacteria in the original sample was determined by multiplying the number of colonies that developed by the dilution. The selective medium for monitoring creosote /PCP acclimated bacteria was consisted of prepared nutrient agar (Difco Laboratoris, Detroit, Michigan) amended with 1 ml of creosote (Koppers, Grenada, MS) and PCP (99%, Aldrich Chemicals, Milwaukee, Wisconsin) solution containing 20 mg/ml creosote and 5 mg/ml PCP in methanol. This solution was added to 1 L of autoclaved liquid nutrient agar.

Results and Discussion

Creosote constituents (PAHs) in influent during 1990 - 2001 averaged 5.75 mg/L while effluent samples averaged 0.16 mg/L or 97% reduction during these years (Figure 1). Naphthalene and phenanthrene were the two major constituents among selected PAHs.

Only small portion of naphthalene removal could be due to volatilization of this compound since reactors were not open systems.

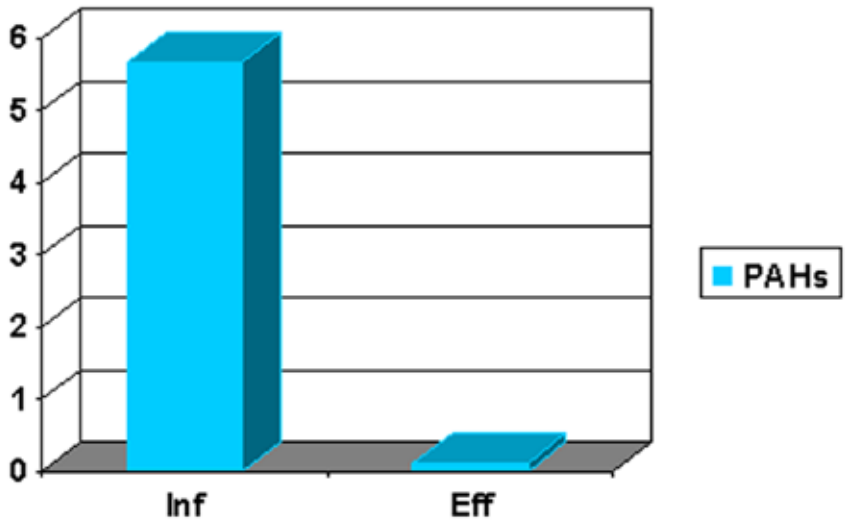

Figure 1: Concentration of selected PAHs during a period of 12 years. The results represent an average of 250 samples.

Pentachlorophenol concentration in influent and effluent averaged 0.042 mg/L and 0.022 mg/L respectively or 44% biodegradation of this wood preservative for the eleven years of sampling period. Tetrachlorophenol concentrations for influent and effluent remained below detection limit of 10 ppb throughout this project. (Figure 2)

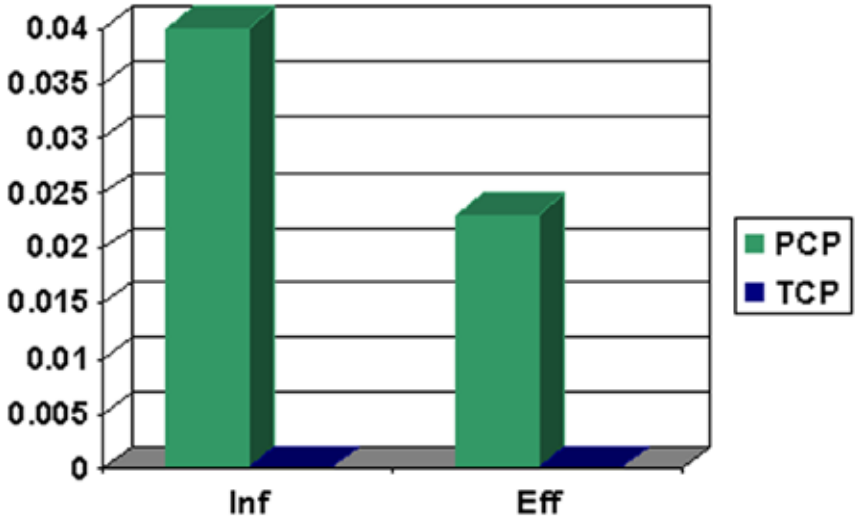

Figure 2: Concentration of selected PCP and TCP during a period of 12 years. The results represent an average of 250 samples.

Biological Oxygen Demand (BOD) results are summarized in Figure 3. Twelve year averages for influent and effluent BOD levels were 15.2 mg/L and 5.9 mg/L or 61% reduction, BOD levels in effluent reached as high as 9 mg/L in hot summer months.

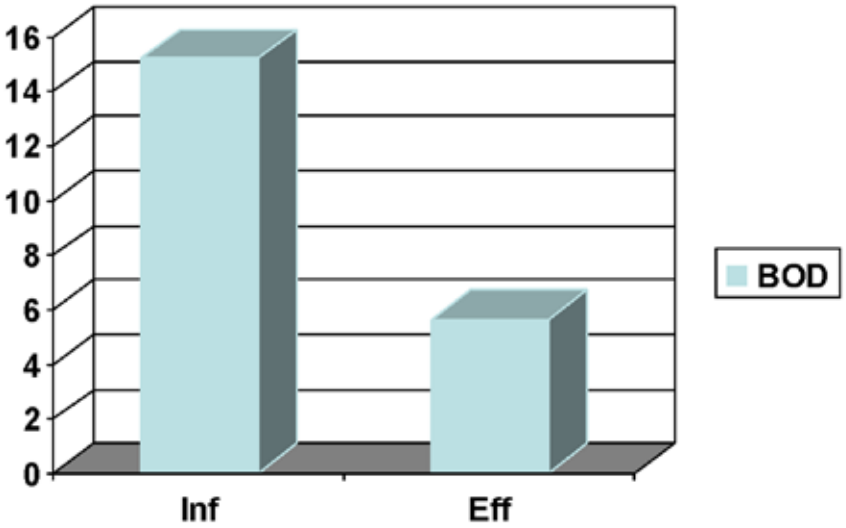

Figure 3: Concentration of selected BOD during a period of 12 years. The results represent an average of 250 samples.

Bacterial population fluctuated throughout the seasons with high numbers in fall, winter, and spring, but low numbers in hot summers. Overall the colony counts averaged for this eleven year period constantly remained over 750,000 colonies/ mL. (Figure 4)

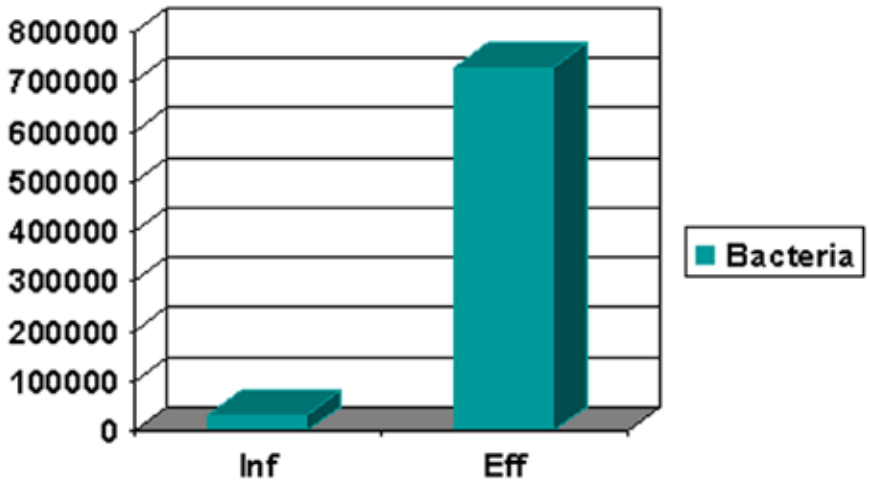

Figure 4: Bacterial Colonies per mL on creosote and PCP amended medium during 12 years of pump and treat. Results represent an average of 250 samples.

Total suspended solids results are shown in Figure 5. Concentrations of TSS in influent and effluent were 12 mg/L and 5.75 mg/L or 54% reduction. Aeration of groundwater removed significant amounts of iron present in most of south Mississippi's groundwater. Iron and other metal percipatants were removed from reactors during annual maintenance and clean up.

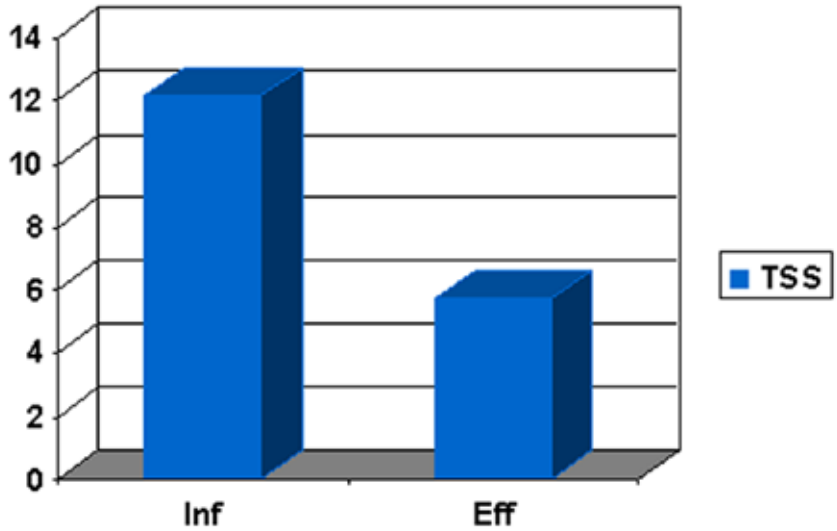

Figure 5: Concentration of selected TSS during a period of 12 years. The results represent an average of 250 samples.

Conclusion

Questions about efficiency of pump and treat systems might be answered by the use of sophisticated data analysis tools such as computerized mathematical models that can indeed be used to make predictions about future performance, but such predictions are highly dependent on the quality and completeness of the field and laboratory data utilized (Keely, 1989). The presented pump and treat system performed well for its intended purposes of preventing migration of contaminants to the surrounding areas and removing significant amounts of pollutants from the groundwater. The site is currently using natural attenuation remediation. During the twelve year study, the pump and treat cost was significantly lower than activated carbon filtration and was less labor intensive for the company considering the heterogeneous nature of contaminants that made it less amenable to treatment.

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