KENAF MEDIUM MULTI-STAGE BIOFILTRATION SYSTEM FOR CLEAN-UP OF CREOSOTE AND PENTACHLOROPHENOL CONTAMINATED GROUNDWATER

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ABSTRACT: A multi-stage biofiltration system was designed and constructed that used three connected biofilter chambers to optimize the conditions for decontamination. Contaminated with 1630 ug/L of selected PAHs and 30 ug/L of PCP, the groundwater was stored in a 30-gallon drum to feed the biofilters. The first and second biofilters were packed with kenaf, with the first biofilter inoculated with *Arthrobacter sp.* and the second chamber containing kenaf alone. The third biofilter contained sand with a small layer of gravel in the bottom of the biofilter chamber. Liquid samples were collected from each biofilter chamber 12 hours after opening the valve. This cycle was repeated three times. At the end of this study, kenaf and sand samples were taken from each chamber for analysis. All PCP was removed from the groundwater after filtering through the first biofiltration chamber in all three replications. The PAHs were removed after filtering through first and second biofiltration chambers in all three replications. Kenaf in the first biofilter removed over 90% of the contaminants. Analysis of the matrices indicated that the two kenaf biofilters adsorbed or biodegraded 100% of PCP and PAHs from the contaminated groundwater. Spent kenaf from the first biofilter chamber was placed in a small planting pot and well mixed with 5% horse manure and composted for 60 days. After composting, the concentration of PAHs in kenaf from chamber 1 decreased from 78.5 mg/kg to 4.71 mg/kg, a 94% reduction. The PCP levels dropped from 5.2 to 1.12 mg/kg a 78% reduction. The level of contamination still remaining in the kenaf after a 60-day composting period was well below the mandate for soil disposal and can be easily disposed.

INTRODUCTION

Traditionally two treatment methods have been applied for cleanup of polluted groundwater, carbon filtration and biological treatment. The cost for carbon filtration of groundwater-containing organic wood treating chemicals averages from $1.25-$5.25 per 1000 gallons, depending on influent levels and types of carbon (Borazjani et al. 1999). This method is labor-intensive and the spent carbon 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.

Biofiltration is an alternative technology that could efficiently clean up groundwater. Biofiltration utilizes highly selected microorganisms capable of degrading a specific compound or group of compounds. Some biofiltration systems have provided biodegradation rates equal to or superior to free-cell systems (Heitkamp et al. 1990; Belfanz and Rehm 1991). Researchers have examined a variety of material for matrices such as pea gravel, plastics, wood

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chips, etc. Matrices should provide a rough irregular surface to allow for maximum attachment and colonization of selected microorganisms (Durham et al. 1994).

Kenaf (*Hibiscus cannabinus*) has received increasing interest as an alternative media or matrix in bioremoval of pollutants from soil and water (Burcham et al. 1999; Diehl et al. 1999). Kenaf medium does provide aerobic treatment and may provide anaerobic biological treatment as well (Burcham et al. 1999). The bast fibers have a high surface area for microbial attachment and colonization. The core material accentuates the absorption of water and oil-based odor compounds and after exhaustion the spent kenaf could be successfully composted and utilized as soil amendments (Burcham et al. 1999).

The contaminants chosen for this experiment were creosote and pentachlorophenol in groundwater. Creosote and pentachlorophenol (PCP) are two major organic wood preservatives that have been widely used by the wood and lumber industry since their development in 1838 and 1935, respectively. Millions of gallons of this preservative are applied each year to railroad cross ties, utility poles, fence posts, and other industrial uses. Sixteen polycyclic aromatic hydrocarbon's (PAHs) found in creosote as well as PCP are named individually by the EPA as priority pollutants.

This study: 1) investigated kenaf as an alternative medium for biofiltration treatment of creosote and pentachlorophenol contaminated groundwater, and 2) examined if composting spent kenaf would biodegrade the adsorbed pollutants.

MATERIALS AND METHODS

For this experiment, a multi-stage biofiltration system was designed and constructed that used three biofilter chambers connected by plastic tubing to optimize the conditions for decontamination. The biofilters were attached to a support system, which held them in a stair step manner, with gravity flow acting as the catalyst for movement, as opposed to actually having to pump the contaminants through the system. The biofilters were constructed of three-foot long acrylic pipes with a PVC cap and a valve system attached to the bottom to collect the samples. Each biofilter had a 4-inch inside-diameter. Plastic tubing was attached to the valves and administered at the top of the next biofilter for the effluent to travel through the multi-stage system (Figure 1). With 1630 ppb of selected PAHs and 30 ppb of PCP the contaminated groundwater was stored in a 30-gallon drum to feed the biofilters.

The matrices chosen for this experiment were ground up kenaf core and sand. The first biofilter chamber was packed with kenaf, inoculated with *Arthrobacter sp.* liquid culture, the second chamber contained kenaf alone and the third biofilter contained sand with a small layer of gravel in the bottom of the biofilter chamber. Sand was chosen to serve as a polishing media for the final stage of clean up (Figure 1).

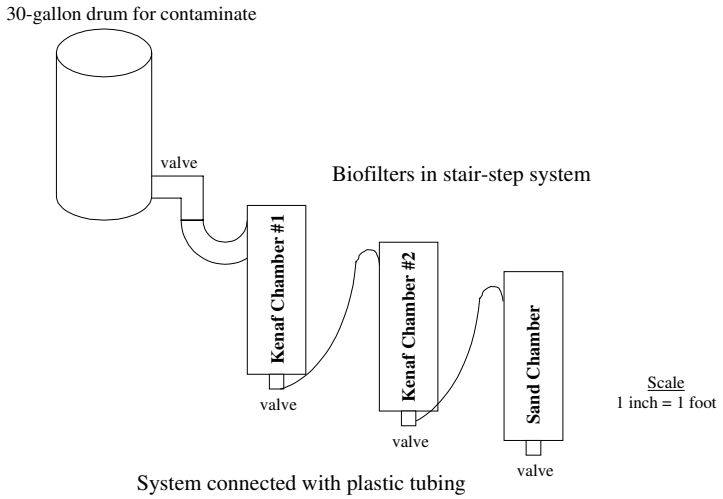

Figure 1. Schematic diagram of multi-stage biofiltration apparatus

Arthrobacter sp. bacterium is a well-known microorganism for biodegradation of PAHs and PCP (Borazjani et al. 1999; Diehl et al. 1999). This bacterium was isolated from a PCP and creosote wood treating plant in Joplin, Missouri and was shown to be an effective biodegrader of PAHs and PCP in the treatment of process water from wood treating operations (Walker 1992). The bacterium was grown on nutrient broth for kenaf inoculation. One liter of *Arthrobacter sp.* culture was directly poured into the first kenaf biofilter and was allowed to remain on the matrix for 12 hours. After a 12-hour period, the bottom valve was opened to allow the excess bacterial culture to exit the system. Biofilter systems were run by opening the valve of the storage drum to a flow rate of 0.007 gal/min. Samples were collected from each biofilter chamber 12 hours after opening the valve. This cycle was repeated for three complete replications.

At the end of this study, kenaf and sand samples were taken from each chamber for analysis. Sand and kenaf samples were extracted by EPA Method 3540 and analyzed for PAHs and PCP by EPA Methods 8100 and 8151. Effluent water samples were extracted by EPA Method 3520 and analyzed for PAHs and PCP with the above mentioned methods (US EPA SW846, 1992). A serial dilution plate technique was used to determine the microbial population.

Spent kenaf from the first chamber of biofilter was placed in a small planting pot and was mixed well with 5% horse manure. Well water was routinely added as needed to keep the moisture content at 50-60%. The pot content was turned twice a week. Composted materials were analyzed for PAHs and PCP concentrations after 60 days.

RESULTS AND DISCUSSION

As the contaminated groundwater moved through the multi-stage biofiltration system, all traces of PCP and PAHs were removed (Table1). All PCP was removed from the groundwater after filtering through the first

biofiltration chamber in all three replications. The PAHs were removed after filtering through the second biofiltration chamber in all three replications (Table 1). Kenaf in the first biofilter removed over 90% of the contaminants. The analysis of the matrices indicated that the two kenaf biofilters adsorbed or biodegraded 100% of PCP and PAHs from the contaminated groundwater (Table 2).

Table 1. Concentration of PAHs and PCP (ug/L) in effluent taken from different chambers.

	Stock	Kenaf 1	Kenaf2	Sand
PAHs	1630	28	0	0
PCP	30	0	0	0

Table 2. Adsorption of PACS and PCP (mg/Kg) on matrices.

	Kenaf 1	Kenaf 2	Sand
PACS	78.5	26	0
PCP	5.2	0	0

After composting, the PACS concentration in kenaf from chamber 1 decreased from 78.5 mg/Kg to 4.71 mg/Kg or 94% reduction (Table 3). PCP levels dropped from 5.2 to 1.12 mg/Kg or 78% reduction (Table 1). The level of contamination still remaining in the kenaf after a 60-day composting period was well below the mandate for soil disposal and could be disposed of without regulation or fear of pollution.

Table 3. Concentration of PACS and PCP in spent kenaf from chamber 1 after 60 days of composting with 5% horse manure.

	Day 0	Day 60	% Reduction
PACS	78.5	4.71	94
PCP	5.2	1.12	78

* The calculation is based on 95% spend kenaf content.

The bacteria were only inoculated on the first kenaf biofilter, but indigenous bacteria were present in the second kenaf biofilter, as well. The kenaf for this study was not sterilized to remove indigenous microorganisms. The total bacteria for the first kenaf biofilter were 910 million colonies (Figure 2), and 960 million colonies for the second kenaf biofilter (Figure 3). The higher bacteria population in biofilter 2 could be due to the reduction or absence of the harmful PCP and PAHs from groundwater filtering through this chamber.

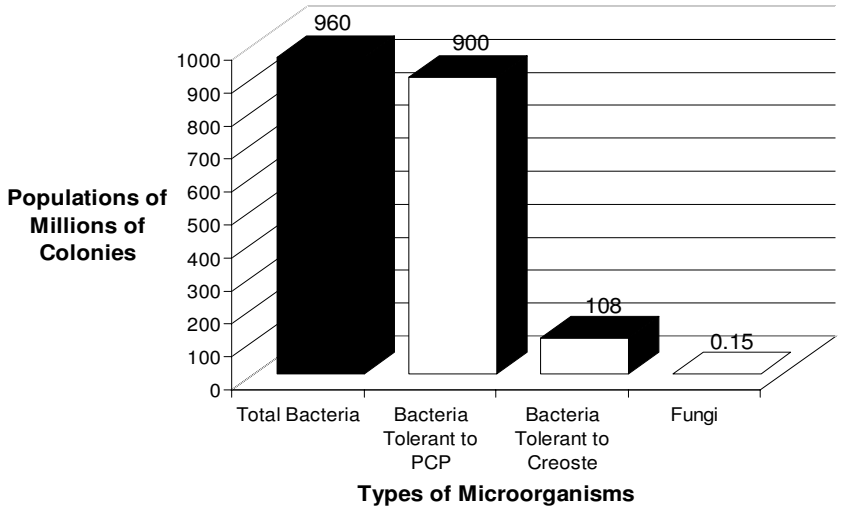

Figure 2. Kenaf Chamber 1 microbial counts.

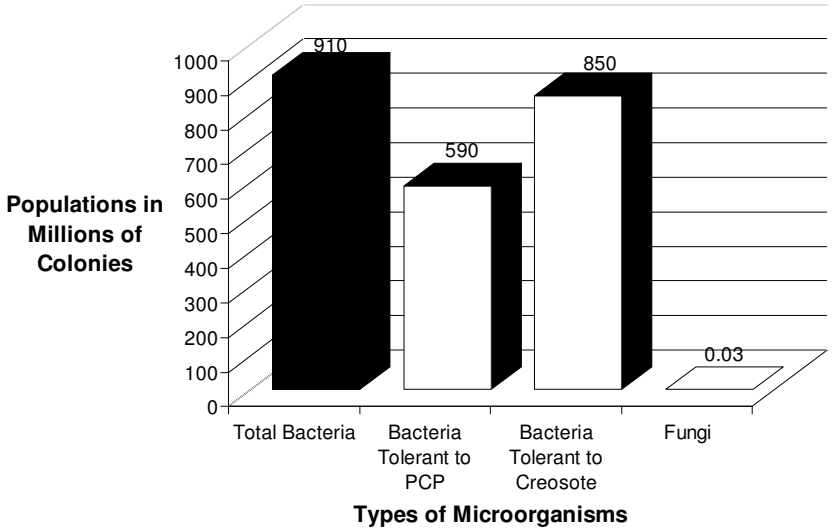

Figure 3. Kenaf Chamber 2 microbial counts.

CONCLUSION

These results showed that a multi-stage kenaf biofiltration system would remove all traces of PCP and PACS from contaminated groundwater. The amount adsorbed on spent kenaf was later biodegraded to levels well below the land ban levels. This may be an important advantage of kenaf matrix to activated carbon.

The removal of the PCP and PACS in this type of system indicated that a multi-stage kenaf biofiltration system would be applicable for today's wood

industry or similar industries. A practical application of this research would be for a large pilot-scale biofilter made of a large PVC pipe packed with the kenaf matrix on a site with groundwater contamination. Pumping contaminated groundwater through this type of biofiltration system could be very economical for the wood industry due to its ease of operation and environmentally friendly nature of materials like kenaf. Future research endeavors include: experimenting with higher concentration levels of contaminants and increasing flow rates to determine if more water could be treated at a faster rate.

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