Fiber Rolls as a Tool for Re-Vegetation of Oil-Brine Contaminated Watersheds - Final Report - Executive Summary

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Title: Fiber Rolls as a Tool for Re-Vegetation of Oil-Brine Contaminated Watersheds
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Objectives: Our primary objective is to examine the utility of fiber rolls as an effective, inexpensive, and easy-to-use remediation tool at oil brine spill sites that do not respond to traditional remediation techniques. We tested whether:

1) fiber rolls and surface soil treatments affect soil chemistry of a historic brine scar,
2) establishment of plants occurs in fiber rolls and treatment plots,
3) fiber rolls trap sediments and maintain their integrity during the 18 month study period.

Summary/Accomplishments: We found that fibrijute burlap cylinders filled with organic matter and inoculated with salt tolerant plants and mycorrhizal fungi promoted remediation of an historic brine scar devoid of vegetation since the 1960's. Soils in plots that received a surface treatment of hay, organic matter and fiber rolls had reduced levels of salt, acidity, calcium and chlorine. However, high variability in soil chemistry measurements within and between treatments suggests caution in the interpretation of results. While fiber rolls maintained their integrity throughout the 18 month study period, no soil accretion was observed on the up-slope side of fiber rolls. However, vegetative response to soil treatments was pronounced. *Baccharis halimifolia* (groundsel bush) and clover planted in fiber rolls survived well. Total vegetative cover was most extensive in plots treated with soil amendments and fiber rolls, while minimal in untreated plots. Volunteer *Baccharis*, along with a diverse variety of grasses and forbs successfully colonized treated plots. Fiber rolls in conjunction with conventional soil treatments appear to be an effective, inexpensive, and environmentally friendly way of promoting recovery of historic brine spill sites.

Introduction: *In situ* bioremediation provides an economical and minimally intrusive method of restoring oilfield brine spill sites. Remediation involves improving soil structure, accelerating salt-leaching, minimizing erosion and achieving rapid recolonization of native plant communities (Evans and Young 1970: Oke 1978; Hopkins et al 1991). The utility of fiber rolls (inoculated with mycorrhizal fungi and salt tolerant plants) combined with surface soil amendments was evaluated as a remediation tool at a historic brine scar in southern Arkansas.

Methods: The fiber rolls installed at the Schuler Oil and Gas Field study site (Union County, Arkansas) are fibrijute burlap cylinders (3 meters long, 0.5 meters in diameter) filed with a 50:50 mixture of hay and composted organic waste and wood chips (horse stall litter). Salt-tolerant plants, including groundsel bush (*Baccharis halimifolia*), wax myrtle (*Myrica cerifera*), salt grass (*Distichlis spicata*), bermuda grass (*Cynodon dactylon*), panic grass (*Panicum virgatum*) and clover (*Trifolium repens*) were planted in each fiber roll. Twelve plots (4 x 36 m in length) were established within the study site. Each plot received one of four treatments; control (no treatment), fiber rolls only, soil amendment only, and fiber rolls plus soil amendment, such that each treatment was replicated three times. Soil amendments included chicken manure spread to a depth 2 cm and hay spread at a rate of 1 standard bale per $36m^2$ (IPEC 2002). A disc was used to mix soil amendments into the top 4 cm of soil. Supplemental water and an additional layer of hay were provided during the first 4 months. Soil samples were collected at the start and end of the study period to quantify pH, electrical conductivity (EC), and quantities of various nutrients and heavy metals including, P, K, Ca, Mg, S, Na, Fe, Mn, Zn, Cu, B, Cl-, NO^3-N, NH^4-N, and Carbon. Plant survival and cover was assessed in all fiber rolls and plots 4 and 7 months post treatment. Roll integrity was assessed by counting the number of breaks or tears in the fibrijute on each roll. Soil accretion on the up-stream side of fiber rolls was examined at the end of the study period with a laser level.

Research Results:

Precision of Soil Chemistry Analysis: In order to evaluate the precision of standard soil testing methods, duplicate test values obtained by re-sampling soils from the same mixed sample was conducted. Some variability in soil chemistry values was detected, despite strict laboratory testing standards. For example, calcium values varied from 8.5% to 13.7% between different tests of the same soil sample. Similarly, changes in sodium values varied from 10.3% to 17.8%.

Surface Soil Chemistry: An examination of surface (0-6 cm) soil chemistry characteristics quantified before and after 9 months of treatment revealed several significant differences between treatments. Control plots and fiber roll only plots (that received no soil amendments) exhibited high variability between pre- and post-treatment sampling periods. Surface soils in control and fiber roll only plots were significantly different in pH, boron NH^4, EC, magnesium, sodium and iron content.

Against this changing background of soil chemistry values, significant differences were noted between soil amendment plots (amendment only and role plus amendment) and plots without soil amendments (control and fiber roll only). Soil amendment plots were consistently higher than non-soil amended plots in levels of phosphorus, zinc, copper NO^3 and iron. Soil amendment plots were consistently lower than non-amended plots in terms of pH, EC, calcium, magnesium, sodium and chlorine.

Several differences between pre-and post-treatment soil chemistry measures were detected (Figure 1). Again, conditions in control plots changed significantly during the study period. In surface soil layers, control plots experienced a significant decline in pH, sodium and iron content while increasing in copper and NH^4. Surface soil in fiber roll only plots experienced a decrease in NH^4, carbon, EC, sodium and chlorine along with an increase in pH and copper. Amendment only plots had declining amounts of boron, calcium, magnesium, sodium and chlorine while increasing in pH, phosphorus, copper, NH^4 and iron. Plots with fiber rolls and soil amendments experienced the greatest number of changes in soil chemistry values. Significant increases were noted in pH, phosphorus, zinc, copper, NO^3, potassium and iron, while decreases were seen in EC, calcium, magnesium, sodium and chlorine.

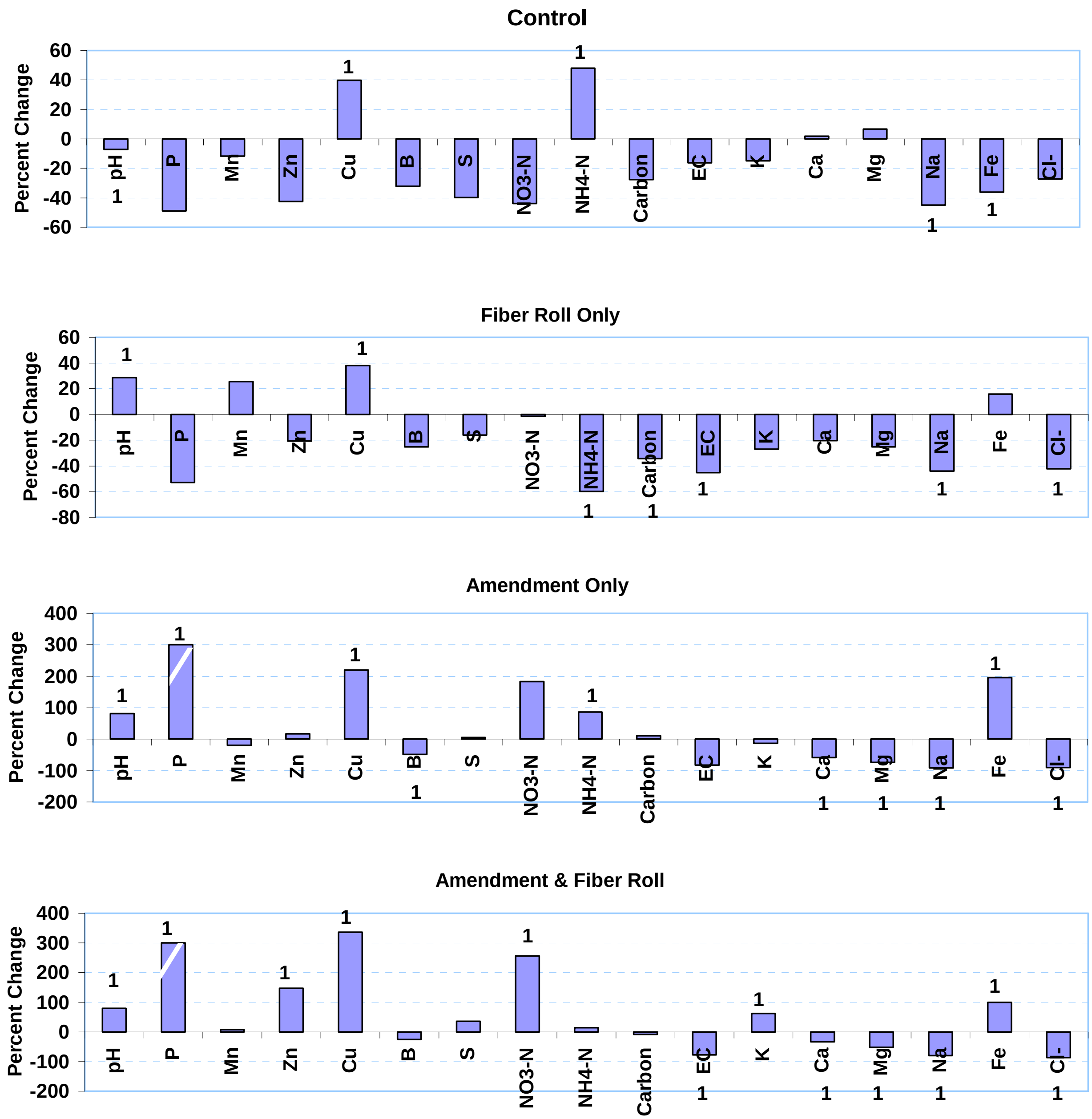

Figure 1. Percent change in surface soil values (between March, 2006 and December, 2006) by treatment. Symbol "1" indicates a significant difference ($P < 0.05$) between pre- and post- treatment values.

Vegetation Cover: The amount of vegetation cover varied significantly by treatment and location within treated plots (on fiber rolls, adjacent to fiber rolls, between fiber rolls). During the first sampling period post-treatment (3/27/2006) vegetative cover was significantly greater on fiber rolls in plots with soil amendments than on fiber rolls in plots without soil amendments. Surface soil amendments also supported increased vegetative cover immediately adjacent to rolls (within 60 cm) compared to un-amended plots. Little growth occurred in areas away from fiber rolls (Figure 2A).

During the second sampling period post-treatment increased vegetation cover was noted on fiber rolls in soil amended plots while vegetation cover declined on fiber rolls in un-amended plots. Vegetation cover increased in soil amended plots adjacent to fiber rolls. Vegetation cover also increased in control and soil amended plots without fiber rolls (Figure 2B).

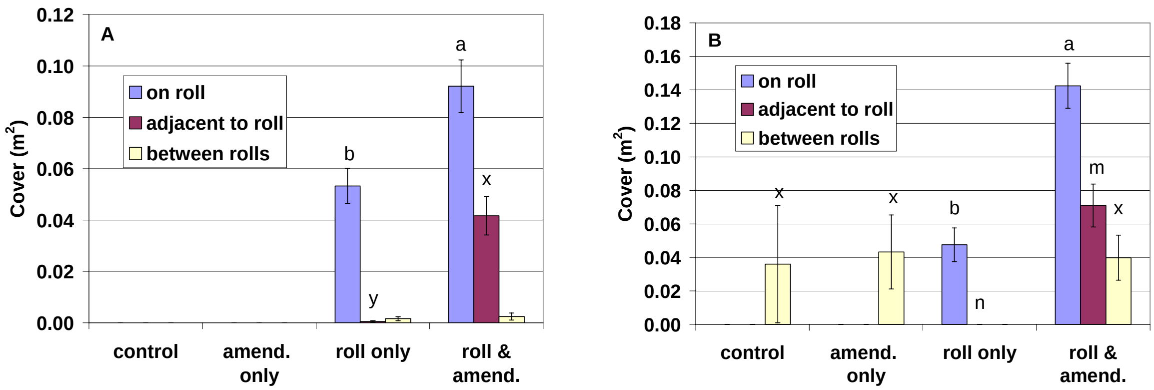

Figure 2. Vegetation cover by treatment, location and time period (A = 3/27/06, B = 5/19/06). Standard error bars with different letters (on roll: a, b, adjacent to roll: m, n, between rolls: x, y) are significantly different by treatment.

Total vegetation cover varied with regard to treatment and time after treatment. During the first sampling period post-treatment total vegetative cover was higher in the roll & amendment plots than in roll only plots. No vegetation cover was observed in the control and soil amendment only plot. During the second sampling period total cover in the roll & amendment plots was significantly higher than the vegetative growth in all other treatments, despite significant vegetation growth in those treatments (Figure 3).

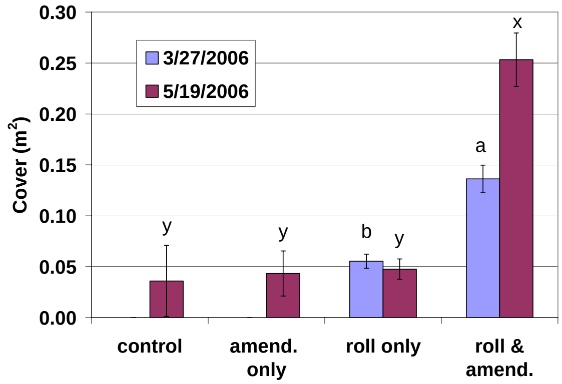

Figure 3. Total vegetative cover by treatment and time period. Standard error bars followed by different letters (3/27/06: a, b, 5/19/06: x, y) are significantly different within time periods.

Vegetation Survival: Plant survival varied by treatment. Survival of some grasses was difficult to assess due to the unavailability of diagnostic flowering parts during sampling periods. Grass seed associated with the hay surface treatment successfully germinated on and between fiber rolls making it difficult to accurately determine survival rates of Bermuda grass and panic grass. However, salt grass and wax myrtle mortality, at 100%, was apparent. Baccharis mortality varied from 40% to 60% in plots with fiber rolls only and roll & amendment plots, respectively (Figure 4). Clover mortality was greater than 90%. Many of the grass and forb seeds associated with hay spread as a surface soil treatment, germinated to comprise much of the vegetative cover on and between fiber rolls. Volunteer Baccharis was also noted in several roll & amendment plots away from fiber rolls (Figure 5).

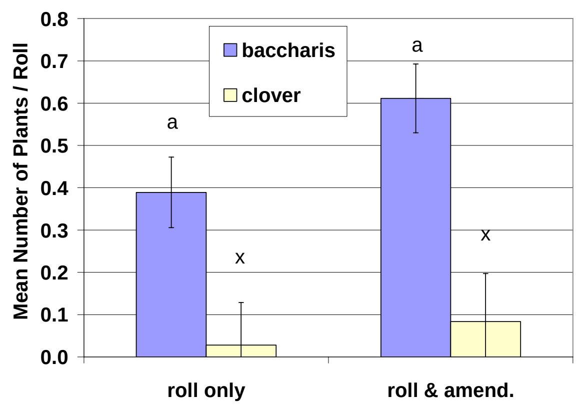

Figure 4. Mean number of plants per roll. Standard error bars followed by different letters (*Baccharis*: a, b, clover: x, y) are significantly different by treatment.

Figure 5. "V-shaped" fiber rolls and volunteer *Baccharis* on a role & amendment plot at the Schuler Oil and Gas Field, south Arkansas, May 19, 2006.

Fiber Roll Integrity and Soil Accretion: No significant breaks or tears in the fiber rolls were detected during the 18-month study period. No significant difference was found between sediment heights above and below fiber rolls (once background changes in slope were accounted for).

Conclusions:

1. Of the four remediation treatments (control, soil amendment only, fiber roll only, and soil amendment & fiber roll) fiber rolls in combination with surface soil amendments was best at promoting vegetation reestablishment at a historic brine scar devoid of vegetation.

2. Groundsel bush (*Baccharis halimifolia*) and clover (*Trifolium repens*) had better establishment success on fiber rolls than wax myrtle (*Myrica cerifera*), bermuda grass (*Cynodon dactylon*), and panic grass (P*anicum virgatum*).

3. Extent of vegetative cover appears to be a better measure of remediation success than direct measurement of soil chemistry and contaminate levels. Direct measurement of soil nutrients and contaminates involves significant variability and does not necessarily reflect their bioavailability.

4. Biodegradable fabijute burlap appears to be a suitable material for fiber roll construction since it maintained its integrity throughout the 18 month study period.

5. The failure of fiber rolls to accumulate surface sediments is attributed to the high saturation flow rate of the sandy soils at our study site and reduced rainfall during the study period. Fiber roll "dams" may be more successful at trapping sediments where runoff is confined to narrow more steeply-sloped channels.

6. Heavy deer browse may reduce vegetation survival and growth on newly established fiber rolls and soil amended plots. More extensive fencing may be needed to reduce browse damage.

References:

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Future Activities: Informal assessment of fiber roll integrity and vegetative cover will continue.

Publications/Presentations: none

Relevant Web Sites: ipec.utulsa.edu, www.osradp.lsu.edu

Supplemental Keywords: bioremediation, brine, brine spill, historic brine site, fiber roll, soil amendment, revegetation, remediation, reclamation, orphan well, abandoned well, *Baccharis*, Arkansas.