Nearby Lake Sediment Quality and Seedling Tree Survival on Eroded Oily Waste / Brine Contaminated Soil

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Summary

An ecosystem restoration study is being conducted at an old oil production area in Northeast Oklahoma. Surface soil samples from areas impacted by discarded crude oil and brine wastes have been chemically characterized. Surface erosion has occurred in areas impacted by waste discharges so only sparse native vegetation is present. Gullies have formed resulting in transport of impacted surface soil into an adjacent lake. Sediments have been collected and analyzed for total and bio-available metals to determine potential effects on the lake ecosystem. The sediments contained toxic levels of barium, cadmium, chromium, and lead. Test plots were established for Black Locust seedlings, Russian Olive seedlings, and Bermudagrass in several impacted areas. After three months growth, the survival rate was 20 and 90 percent for Russian Olive and Black Locust trees, respectively.

Introduction

Hydrocarbon and produced water releases can occur in oilfield operations as a result of equipment failures and other accidents. These releases, the disposal of water produced with oil and gas, and restoration of effected areas are natural issues that concern watershed managers as well as regulators, surface landowners and local residents. Most of the releases frequently were related to past acceptable oilfield practices. Studies are now needed to evaluate and restore the ecosystems by cost effective techniques.

The two research sites are located adjacent to a lake northwest of Tulsa, Oklahoma. Both sites have a long history of petroleum production with the highest activity occurring in the 1930's. Crude oil and brine water have impacted the landscape by erosion and contamination of the surface and disappearance of the native plants.

The objective of the study was to determine the heavy metals associated with eroded surface soil that is now lake sediment. Also, as study was conducted using test plots to determine survival of three plant species planted into impacted soil.

Experimental Methods

Lake shore-line sediments were collected with a seven inch wide LaMotte clam-type steel sampler in about six inches of water. The samples were placed in 125 mL polyethylene bottles, and then capped for transport back to the laboratory. The sediments were air-dried and digested in 10% nitric acid for total metals analysis using an ICP-Emission spectrometer. Duplicate dry sediment samples were extracted with a dilute calcium nitrate solution (An etal, 2003). The extract solutions were analyzed for metals and reported as bio-available metals.

Two 8x40 foot plots on bare ground were selected at each Site A and Site B location. The plots were tilled using a small powered rotor-tiller. Each 8x40 foot was divided into five 8x8 foot plots. Black Locust and Russian Olive seedlings were alternately planted equal distances apart in the 8x16 foot outer plots. The center 8x8 foot plot was planted with Bermudagrass seed. Straw mulch was placed on top of the planted grass seed. The plots were established during March. The field site was visited every six weeks and observations were recorded.

Besides metals, soil salt and nitrates were determined on the sediments and plot soil samples. Soil nitrates were measured on a dilute acid extract of 95% distilled water and 5% mix of sulfuric and hydrochloric acids using a cadmium reduction method (EPA Standard Method 353.3). Soil salt was determined using the IPEC Soil Salt Analysis Kit.

Results and Discussion

Regulatory limits of toxic heavy metals under RCRA guidelines are listed in Table 1. The concentrations listed are for water, but are shown for soil by assuming ppm for both water and soil are equivalent and that soil metals are all water extractable. Table 2 lists total metals present in the shore-line sediments. Toxic levels were exceeded for barium, cadmium, chromium, and lead. None of the samples contained measurable amounts which were > 1 mg/Kg of bio-available metals.

Analyses of the two Site A and two Site B test plot soils are listed in Table 3. Soil salt was much higher in the Site B plots. All plots had levels of barium, cadmium, chromium, and lead that exceeded the RCRA toxic levels. This may not actually be true because assumptions were made that all metals associated with the sediments were water extractable. Our approach was to show that the potential for toxicity does exist. The survival of seedling threes in the test plots after a 2003 March to June growth period is shown in Table 4. The establishment of Black Locust trees did not appear to show any detrimental effect of higher soil salt in the Site B plots. Russian Olive trees that survived after three months growth did not have a vigorous appearance characteristic of the Black Locust trees. Three months after planting the Bermudagrass seed the establishment of plants was rather sparse. Appearance was that the cool spring weather did not favor grass seed germination and growth.

The information obtained from the test plots showed that for developing an effective restoration program Black Locust trees should be established.

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References

1. An, Youn-Joo and D.H. Kampbell, "Total, Dissolved, and Bio-Available Metals at Lake Texoma Marinas". Environmental Pollution 122 (2003).

2. EPA Standard Method 353.3. Methods for Chemical Analysis of Water and Wastes. © March 1997 Cincinnati, OH; Environmental Monitoring & Support Laboratories, Environmental Protection Agency.

Table 1:

Regulatory Limits of Toxic Heavy Metals under RCRA

Metal	Regulatory Limit
Arsenic	5.0 mg/Kg
Barium	100.0 mg/Kg
Cadmium	1.0 mg/Kg
Chromium	5.0 mg/Kg
Lead	5.0 mg/Kg
Mercury	0.2 mg/Kg
Selenium	1.0 mg/Kg
Silver	5.0 mg/Kg

Toxic Heavy Metals Without Established Regulatory Limits

Antimony
Beryllium
Nickel
Thallium

Table 2:

Lake Shore-Line Sediments

(mg/kg)

	ASEL 1	ASEL 2	BSEL 1	BSEL 2	BSEL 3	Mean
Soil Salt	105	90	250	140	80	**133.0**
Nitrates	0.07	0.08	0.08	0.08	0.13	**0.09**
Arsenic	ND	ND	ND	ND	13.6	---
Barium	*221.0	*112.0	*145.0	*133.0	* 83.0	---
Beryllium	ND	ND	0.83	0.67	0.90	**0.80**
Cadmium	*1.2	0.9	*3.1	*2.5	*5.5	***2.6**
Cobalt	3.3	4.2	6.8	6.0	9.4	**5.9**
Chromium	*10.0	*8.8	*26.0	* 21.0	* 35.2	***20.2**
Copper	2.1	1.8	7.3	7.0	1.8	**4.0**
Manganese	130	262	192	288	634	**301.2**
Nickel	4.9	5.0	15.4	13.1	10.8	**9.8**
Lead	4.8	*6.6	*12.4	*11.8	*17.0	***10.5**
Strontium	14	13	56	53	16	**30.4**
Titanium	81	76	151	143	113	**112.8**
Vanadium	14	11	36	29	52	**28.4**
Zinc	13	14	46	44	37	**30.8**

* Toxic Level Exceeded

Table 3:

Test Plot Soil

	A Plot 1	A Plot 2	B Plot 1	B Plot 2
Soil Salt (mg/kg)	70	50	2000	9500
pH	6.0	6.0	7.3	7.1
Nitrates (mg/kg)	0.05	0.05	0.06	1.30
(mg/kg)				
Arsenic	ND	ND	ND	ND
Barium	*126	*377	* 124	*115
Beryllium	ND	ND	ND	ND
Cadmium	0.86	0.89	*1.41	* 2.04
Chromium	* 8.2	*6.5	*10.6	*12.9
Copper	2.7	2.7	3.1	4.1
Nickel	3.8	2.9	6.0	7.6
Lead	*7.2	* 6.3	* 6.4	*10.0
Strontium	30	31	49	68
Titanium	126	65	239	206
Vanadium	14	10	21	24
Zinc	15	19	20	28

* Toxic Level Exceeded

Table 4:

Survival Rate of Seedling Trees

Black Locust	90%
Russian Olive	20%