BIOREMEDIATION OF OIL-CONTAMINATED SOIL BY LANDFARMING:

ASSESSMENT OF SOIL QUALITY USING A FIELD TEST KIT

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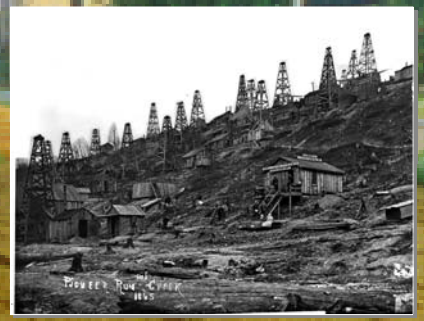
Abstract. Successful remediation of oil-contaminated soil is often measured by the attainment of a baseline concentration of total petroleum hydrocarbons (TPH), frequently set at 10,000 mg/kg (1%). Although this concentration of TPH is believed to minimize toxicity to humans and reduce the substantial threat of oil discharge into the navigable waters of the United States, it does not address toxicity to other organisms or deleterious impacts on overall soil quality. In northwestern Pennsylvania, the plugging of leaking abandoned oil wells near waterways generates oil-contaminated soils that the U.S. Environmental Protection Agency remediates in small landfarm plots. In this study, we used a soil quality test kit, developed by the U.S. Department of Agriculture, to assess soil health at ongoing and completed landfarm plots. The kit, which can be assembled from readily available materials, measures numerous physical, chemical and biological components in soil, such as water infiltration, bulk density, aggregate stability, soil slaking, pH, soil respiration, earthworm abundance, and other parameters. In addition, soil water repellency (MED), cation exchange capacity and methanol-extractable TPH were measured. Results showed that residual crude oil components in remediated soil continued to adversely impact the water-holding capacity of soil in landfarm plots. Certain soil quality measurements for oiled soils, such as soil aggregate stability, could not be directly compared to unimpacted soils, but were useful in identifying the spatial distribution of contaminated soils. The MED method provided rapid and reliable estimates of TPH in landfarm soils in the Bradford region.



Northwestern Pennsylvania, 1865

Well plugging operation, Bradford, PA

Landfarming operation, Bradford, PA

Introduction

The great commercial drilling of petroleum in the United States began at the Drake Well near Titusville, PA in 1859. For the next few decades, Pennsylvania was the world's largest producer of oil. Today, oil still seeps to the surface of uncapped and abandoned wells. The U.S. EPA and PA Department of Environmental Protection continue to plug abandoned wells that threaten to pollute surface waters as time and money allows. Small landfarms are used by the EPA to remediate oil-contaminated soils generated during these plugging operations in the Bradford (McKean Co.) region in lieu of sending the material to landfills.

In this study, we investigated the potential use of relatively simple soil quality tests to evaluate the status of soil quality at landfarms in Bradford, PA. The test kit used was developed as a screening tool to assess the general trend of agricultural soil quality by the U.S. Department of Agriculture. The various tests were devised to be relatively quick, simple and inexpensive to run. Although the EPA target for bioremediation in landfills is ca. 10,000 mg/kg total petroleum hydrocarbons (based on human toxicity guidelines), we were interested to know how benchmarks of soil quality were influenced by the oil bioremediation process. In addition, we were looking for suitable inexpensive tests that could be used by EPA contractors to rapidly evaluate bioremediation efficiency in the field.

Materials & Methods

Seven different hydrocarbon bioremediation sites (biopods) in the Bradford, PA region were sampled in June, July, August, and September 2003. Sites had received oily wastes anywhere from 0 to 7 years prior to sampling. Active biopods were rototilled 3x per week and received periodic fertilizer amendments. One site (McCracken Farm) was routinely sampled at 15 locations on a grid inside and outside the biopod area; the tilled area was ca. 190 m² (10 x 19 m).

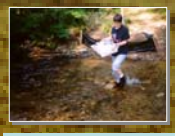
Tests described in the Soil Quality Test Kit Guide (USDA, Soil Quality Institute, 1999) were done on uncontaminated control soil samples to which increasing concentrations of oily waste sludge from a well plugging operation were added. These tests included electrical conductivity, pH, soil nitrate, and aggregate stability. In addition, methanol-extractable total petroleum hydrocarbons (SiteLab field method), molarity of ethanol droplet (MED), and effective cation exchange capacity (barium chloride exchangeable; CEC_e) analyses were done. The following tests were also conducted at field sites: soil respiration, infiltration, bulk density, and earthworm counts.

McCracken biopod

Bulk density test at Rixford site

Earthworm counts

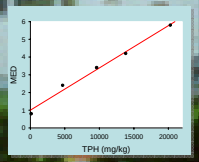
Soil respiration test



Test kit components were easily transported to remote field locations

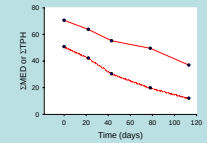
RESULTS

TPH vs. MED



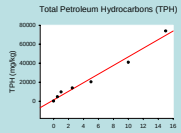
One of the more interesting observations was that the simple MED test (which entails adding droplets of ethanol between 0 and 6 M until beading on the dried soil (above right) no longer occurs after 10 sec (below right)) correlated extremely well with SiteLab TPH estimates in sludge amended soils. SiteLab estimates in turn correlate well with those of conventional EPA method 1664, suggesting that many more samples and more immediate results can be obtained in the field using this simple approach.

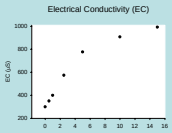
Trends in MED and TPH at McCracken 2003

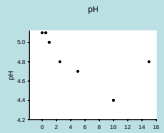


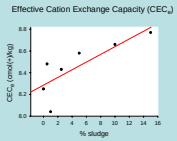
•TPH and MED measurements (shown as summed values for 12 points in the McCracken biopod) both yielded similar information, showing the simultaneous decrease in TPH and general water repellency over the summer of 2003

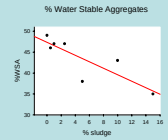
Effects of oily waste sludge from well plugging operations on uncontaminated soil











•Percent added sludge was accurately detected as TPH using the SiteLab fluorometric method

•EC and CEC_e both tended to increase as sludge was added to soil, while pH and % water stable aggregates decreased

•Some variable measurements tended to depart from linearity as sludge concentrations became excessively high (e.g. EC and pH)

In summary, many of the tests in the USDA soil quality kit were useful in differentiating oil-contaminated soil from uncontaminated soil. High sludge applications at new biopods limit the usefulness of many tests until hydrocarbon concentrations drop to values less than 2% TPH. Other tests related to the physical characteristics of soil (e.g. infiltration, bulk density, slake test, etc.) are not applicable to the comparison of tilled active biopods vs. older closed sites or control sites outside the biopods. Earthworms were not found in recently contaminated sites, and they appeared to avoid old sites as well. Electrical conductivity, apparently related to the presence of salts in the waxy sludge material, was a simple test that successful differentiated oil contaminated soils up to 7 years old. This test was less useful in active biopods, where added fertilizer can contribute to EC levels.

CONCLUSIONS

•Several tests in the USDA soil quality test kit proved useful in rapid differentiation of oil sludge-contaminated vs. control soils in the Bradford region. These included pH, EC, and aggregate stability. Other tests in the kit gave results reflective of the degree of oil contamination, but were deemed too labor intensive for the data collected (e.g. soil respiration). Other tests were not useful in the comparison of tilled vs. untilled soils (e.g. infiltration and bulk density).

•The MED test was shown to be an effective estimator of TPH concentrations in Bradford soils in the range 0 – 20,000 mg/kg. Since 10,000 mg/kg TPH is a typical target concentration for the closure of these biopod sites, it appears that the method could be used to estimate TPH at these sites in a cost effective manner. More samples can be run in a shorter period of time than with conventional lab analysis, avoiding the need for composite samples that give little information about the distribution of oil contamination.