Co-composting Treatment of Hydrocarbon Impaired Drilling Wastes

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Abstract

Selecting an appropriate method for disposal of hydrocarbon impaired drilling waste involves a number of fundamental issues; regulatory compliance, environmental risk and liability, cost effectiveness, environmental impact, and time sensitivities. In the past, land treatment of hydrocarbon impaired drilling waste was common throughout Western Canada. Land treatments had demonstrated successful treatment of oily drilling wastes and had provided operators with 'cradle to grave' management. Due to climate and land restrictions, land treatments may not be the most effective option. Alberta Energy and Utilities Board's Drilling Waste Management Guide 50 makes a provision for innovative drilling waste management options. An alternative process to treat hydrocarbon impaired drilling waste has been developed. The objective of this presentation is to review the field and laboratory data associated with co-composting of hydrocarbon impaired drilling wastes.

Several pilot studies have generated sufficient data evidencing the successful bio-degradation of hydrocarbon impaired drill cuttings using co-composting technology. This is a two stage procedure in which cuttings are first co-composted in a one-time constructed, non-reactor based process. Co-composting systems require a smaller footprint, perform in extreme environmental conditions, and provide accelerated biodegradation. Co-composting continues until a practical disposition is achieved. The cured compost is then land applied on operator disposition areas to complete the treatment process. Environmental endpoints have been met by engaging the best possible land application techniques. Cured compost media has been exposed to a multitude of leachability, toxicity, and physical characterization studies; and is found to meet compost maturity criteria as set out by the CCME, BNQ, and AAFC.

The final disposition of the co-composted material is controlled to optimize synergies between the co-compost and the existing soil environment. The resulting media is a nutrient and organic-rich, value added product which is useful in reclamation of the well site or associated activity areas. Based on our research, this procedure is conclusive and does not need to be repeated to ensure assimilation.

Introduction

Oily waste is a by-product of drilling operations. It is produced in large quantities and it's final composition is influenced by drilling fluid chemistry, additives used during operations and formation structures. Possible management options for these impaired materials include:

- Landfill Disposal;
- Landfarming / landtreatment systems;
- Encapsulation / stabilization;
- Thermal destruction or recycling; and
- Washing and recovery systems.

Landfill disposal is, by far, the most common disposal option for these wastes in Alberta however, many operators choose to manage these wastes on their own property, thereby maintaining liability control 'on-site and in-field'. Outside of Alberta there are increased restrictions on burial of such materials, and treatment is required to address future liability issues. Soil conservation, waste recovery, recycling, conversion, and resource management concepts have been a major driving force for effective bioremediation techniques. Bioremediation requires time, space, favourable physical, chemical and biological conditions as well as maintenance to ensure adequate performance.

Land treatments had demonstrated successful treatment of oily drilling wastes and had provided operators with 'cradle to grave' management. However, due to our climate and land restrictions, it was clear that land treatments were not the most ideal method of drilling waste management. Solutions were required for restrictions imposed by land treatment systems; timely management, large land disturbances, aggravation of native soils, and potential reclamation difficulties. Co-composting systems require a smaller footprint, work in extreme environmental conditions, and provide accelerated biodegradation. Data presented in this paper evidences the successful decomposition of petroleum hydrocarbons.

Compost Defined

Composting is a controlled biological process by which organic materials are converted by microorganisms into innocuous, stabilized by-products (1). The process of composting reduces organic matter into carbon dioxide, water, heat, and humus. Composting techniques in agriculture date back to the 12th century, with major scientific enhancements developed in the early 1900's (2). The composting process is also, by definition, a self heating process, whereby the decomposition process releases energy in the form of heat. Compost temperatures follow a predictable pattern as the process evolves with spikes and drops impacted by aeration events and internal conditions.

In the past 15 years, composting technology has developed as an excellent remediation and land reclamation option. Composting systems have demonstrated effective remediation of biodegradable organic compounds, including but not limited to petroleum and non-petroleum hydrocarbons, explosives (TNT, RDX, HMX), ammonium picrate (yellow-D), and organic pesticides (1). Petroleum hydrocarbons including diesel, gasoline, crude, kerosene, and mineral oils are biodegradable utilizing composting techniques.

Co-compost Amendments

Wood fibre (e.g. post peelings, bark, wood residuals) has demonstrated suitability as the primary stabilization and bulking agent within the compost media. Wood fibre provides the aerated structure required for these aerobic treatment methods, as well as available carbon, to the composting system.

Wood fibre products are commonly acquired through local forest product producers (e.g. sawmills), where that material is a waste by-product. Petro Canada and Suncor have taken the initiative to generate wood fibre resources from wellsite 'slash' and 'rootstocks' which would traditionally be burned in many regions. This use of on-site carbon provides excellent carbon recycling and reduces emissions from construction activities.

Trademark composting products have been developed to provide optimal nutrient levels and enhanced rates of biodegradation. ProActivate products (I, II, & III), provide ideal nutrient levels to ensure biological activity is limited only by available carbon levels. Programmed nutrient levels are kept at optimized bioremediation standards by balancing nitrogen and phosphorous with available carbon. Typical programs optimize available carbon to nitrogen at 40:1 ratio, with phosphorous content at 1/10 that of nitrogen levels.

Laboratory data confirms the success of this method of 'maintaining' windrow fluid stability. Figure 1 shows the results of 22 treatments designed and monitored under laboratory conditions.

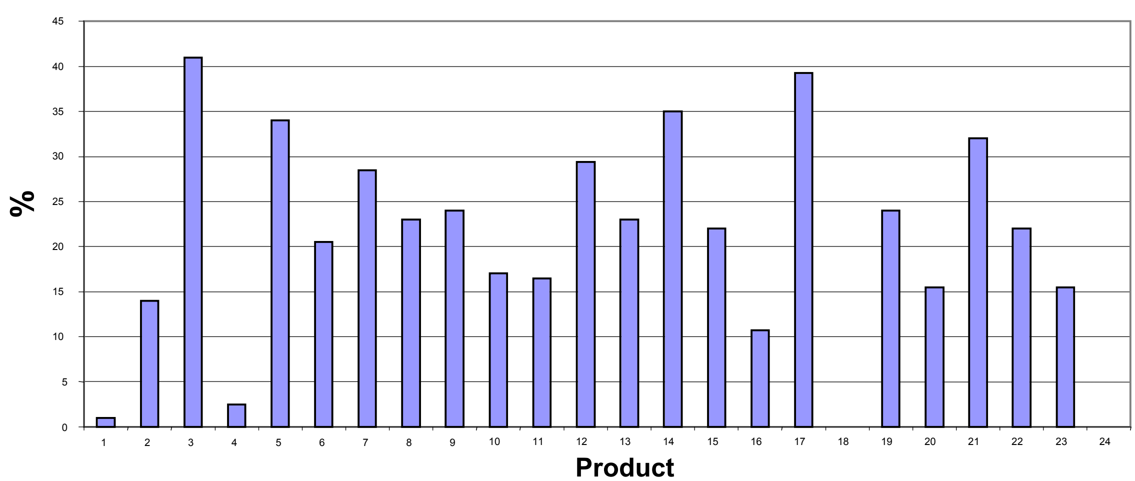

Figure 1. Percentage of Hydrocarbon Biodegradation

The purpose of this experiment was to monitor the performance of various surfactants in laboratory conditions and calibrate the results against a control. Sample one is a blank, sample two is the control and the balance of the listed items are various commercially available products. ProBioxyl is product five in Figure 1. ProBioxyl has demonstrated the ability to increase moisture holding capacity by up to 31%, reduces nutrient leaching to trace levels, and assists in aeration of the compost material. The results provided list those surfactants in concentrations to optimize the amount of carbon dioxide produced. Other surfactant concentrations and combinations utilized in this experiment have not been presented as they yielded poorer performance. Surfactant concentrations ranged from 0.5 to 3 percent by mass. All other variables were constant. Carbon dioxide was measured in the laboratory as a surrogate to calibrate biodegradation (3).

Percent hydrocarbon biodegradation has been calculated as the difference in hydrocarbon concentration between pre and post treatment expressed as a percentage of the pretreatment hydrocarbon concentration. Analysis was completed by a third party laboratory measuring total extractable hydrocarbon by GC/FID.

The best performing products in the laboratory were then assessed under field conditions. Of the products selected to assess field performance, ProBioxyl provided the most consistent results under real conditions. It had been selected for incorporation of the co-composting process. Further research has been directed toward other products including product 14, and product 17. Aside from field performance, cost and relative quantity of each surfactant were considered as desirable factors.

Co-compost Process

Co-composting is a waste treatment method which facilitates the biodegradation of hydrocarbons in spent drill cuttings. This method applies to hydrocarbon and synthetic based mud systems. This is a two stage procedure in which cuttings are first co-composted in a one-time constructed, non-reactor based process. Co-composting continues until a practical quality is achieved. The compost is then land applied on the operator's disposition to complete the treatment process. Environmental endpoints are met by engaging the best possible land application techniques. The final disposition of the co-composted material is controlled to optimize synergies between the co-compost and the existing soil environment.

There are several fundamental 'conditions' required for effective biological remediation of petroleum hydrocarbons. These are:

- structural parameters;
- microbial quality;
- carbon type;
- macro & micro-nutrient levels;
- oxygen availability;
- moisture content; and
- trace elements.

All of these must be balanced to optimize degradation rates. The co-composting system presented here is designed to effectively treat elevated petroleum hydrocarbons. Concentrations in excess of 200,000 parts per million (ppm) have responded to co-composting.

Composting While Drilling (CWD) is a procedure which eliminates the need for containment sumps and tanks and permits the co-composting process to commence upon drill cutting generation. CWD facilitates material blending of initial compost media on location. This procedure:

- reduces waste storage requirements;
- removes the potential of cross contamination of freshwater wastes;
- protects groundwater and soil resources from potential contamination; and
- initiates the composting process prior to rig release.

The stabilized piles created during the CWD process are formed into windrows, aerated, and routinely monitored. Windrows are periodically 'turned' using heavy construction equipment to stimulate aeration. At this time amendments are applied as required to ensure oxygen levels, moisture content, and nutrients maintain optimal levels. This process has undergone trials in laboratory conditions to simulate performance in the field.

Generation of heat via breakdown of organic matter is fundamental to maintaining active degradation throughout the year. These self-heating windrows are successful in most North American climates. Exothermic reactions have maintained effective decomposition with ambient air temperatures of –50 ^{o}C. Figure 2 shows how hydrocarbon content decreases in relation to internal compost pile temperatures.

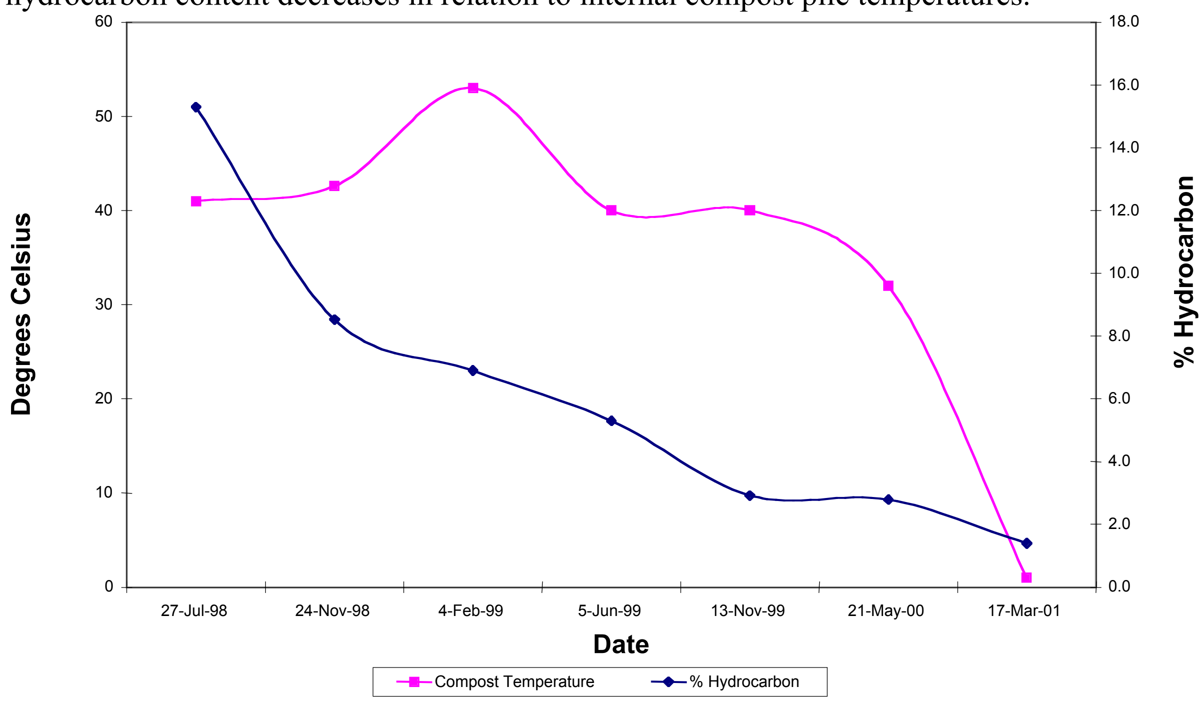

Figure 2: Hydrocarbon Content and Corresponding Temperature in a Typical Compost Pile (Semi-log)

Compost bioactivity, petroleum hydrocarbon concentrations, moisture content, and nutrient levels, are monitored until the composting process is midway into the curing stage. During this period, much of the available carbon has depleted and compost temperatures approach ambient air temperature. Prior to land application, an assessment of residual hydrocarbons, compost maturity, and toxicity issues is initiated. At maturity, the compost is deemed to be at or near a treatability end-point. At this stage, further degradation of the residual hydrocarbons has little effect in a windrow format. Our studies have shown that mature compost will contain a certain amount of residual petroleum hydrocarbons however, once land applied concentrations decrease generally within eight months to acceptable closure limits. Windrow composting yields degradation rates of 90% in the active phase, with a further 5-8% in the final curing stage. Degradation rates for diesel, distillate, mineral oils, and similar products typically ranges from 300 – 500 ppm per day in the active phase with 100 – 200 ppm per day into the final stages of windrow composting.

Hydrocarbon content in the surface applied material was found to meet Guide 50 Drilling Waste Management criteria for release for a pilot project in the Wildcat Hills (WCH). Average hydrocarbon contents at 681 total project days was 3707 mg/kg in the compost material (Figure 3).

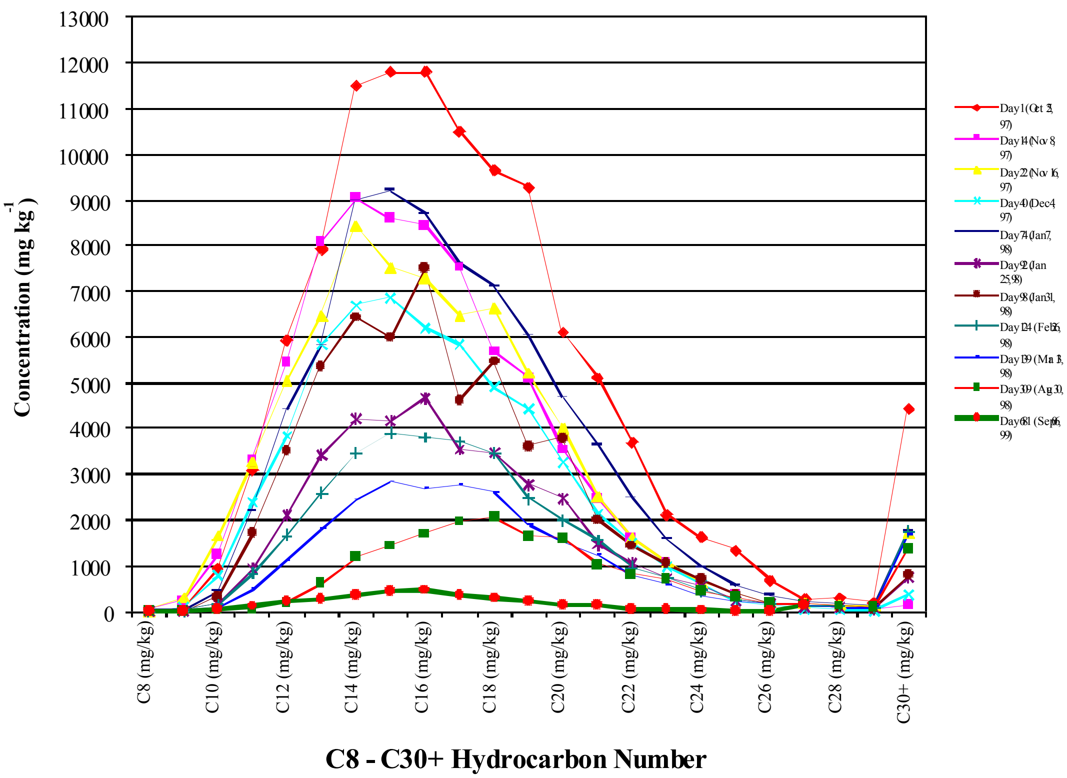

Figure 3. WCH Pilot Project – Hydrocarbon Content and Range

Equipment

Several compost mixing and 'turning' systems were trialed during the development of this procedure for oilfield drilling wastes. Our research has shown the ALLU™ hammermill buckets to be the most effective. The mixing rate may be somewhat reduced when compared with horizontal turning systems however, the units more than compensate in flexibility for windrow size and tolerance to many site conditions.

Compost Stability

Water management is an integral portion of the treatment program. In general, any fluids generated from treatment windrows are recycled through the compost matrix to provide the moisture required for optimum degradation. Water generation may occur as interflow within the compost windrow. In extreme cases, the water may require removal from the treatment system. In these instances, the water is analysed to determine if it meets with the effluent standards detailed by local environmental legislation.

Charted data illustrating the results of our lab scale Toxicity Characteristic Leachate Procedure (TCLP) study are seen in Figure 4. The TCLP analytical procedure is designed to determine the mobility of contaminants present in liquids, solids, and multiphasic wastes (4). This study included analyses on all stages of the composting process with total hydrocarbon content ranging from 19,000 to 207,000 ppm. The oil content available through the TCLP test was found to be very low at 0.1 to 26.5 ppm, with an average concentration of 13 ppm Total Petroleum Hydrocarbons (TPH) in the extract.

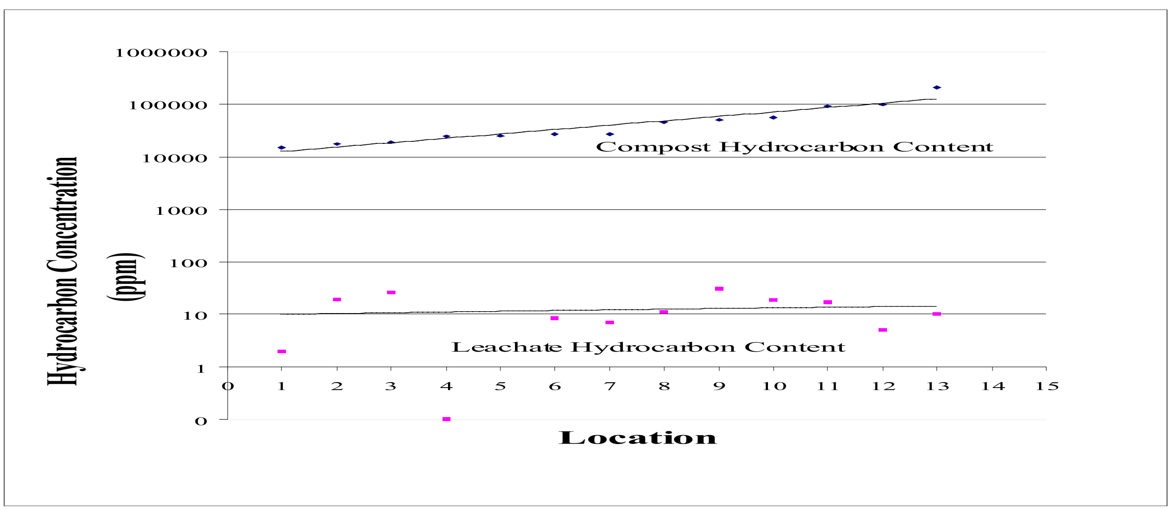

Figure 4. TCLP Leachate Hydrocarbon Analysis of Existing Compost Treatment Media (Semi-Log)

Data were compiled from assessment of actual fluids collected at a group of treatment sites in 1999, a very wet year. This data indicates that our programmed compost blends and ProBioxyl provide excellent 'in field' containment of possible hydrocarbon contaminants. The highest recorded hydrocarbon level in the actual leachate was 9.6 ppm, with typical results measured below 2.0 ppm (Figure 5). A portion of this trace value will also reflect naturally derived hydrocarbons that may be present due to wood fibre degradation (ie. resin acids, fatty acids, and humic acids). This analytical assessment demonstrates that the mobility of petroleum hydrocarbons in compost is highly restricted at various saturation levels.

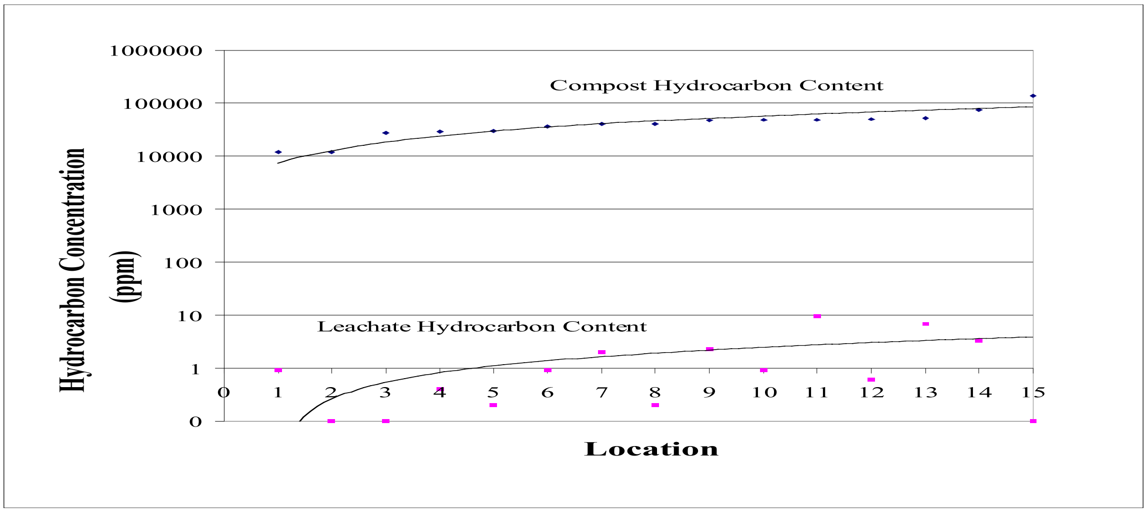

Figure 5: Hydrocarbon Analysis on Actual Leachate Contained at Special Waste Treatment Facilities (Semi-log)

Maturity and Toxicity Testing

Results of analysis indicate mature, land applied co-compost meets release criteria for traditional drilling waste management as outlined in the Alberta Energy and Utilities Board Guide 50 document for Drilling Waste Management (5). Additional data was required to further utilize these materials as soil amendment beyond well site boundaries.

Over 60 mature compost windrows were analyzed for biological toxicity. Over 95% of our compost meets the Canadian Council of Ministers of the Environment (CCME) Category 'A' compost consumer quality criteria (6). The remaining 5% meet Category 'B' CCME compost standards for use in industrial areas. The low trace elements are not due to the composting process. Low concentrations are due to good drilling fluid product screening by industry.

Ecotoxicity assessments routinely include the MicrotoxTM test (Vibrio Fischeri) (7) in conjunction with Radish (Raphanus sativus) and Cress (Lepidium sativum) germination and 14 day biomass measurement. Alternative screening has included germination and biomass of Northern Wheatgrass (Agropyron dasystachyum), lettuce (Lactuca sativa var.), alfalfa (Medicago sativa var.), corn (Zea mays var.), and oats (Avena sativa var.). Invertebrate sensitivity has also been assessed through redworm (Eisenia fetida) avoidance and survival testing which also measured no toxic effects (8).

Consistent MicrotoxTM non-toxic results on all mature projects are significant. It demonstrates the benign status of the end-product and it's ability to meet environmental end-points.

Subsurface Incorporation

Sixteen randomly selected compost windrows were sampled to assess the amount of hydrocarbon within the underlying soil. Representative soil samples from surface to 15 centimetres below grade were submitted for analysis of total petroleum hydrocarbons.

This data indicates that there is little hydrocarbon interaction between the compost and the soil interface at the treatment sites. Naturally occurring hydrocarbons may be contributing to background levels as evidenced in Figure 6. A possible source includes wood fibre degradation.

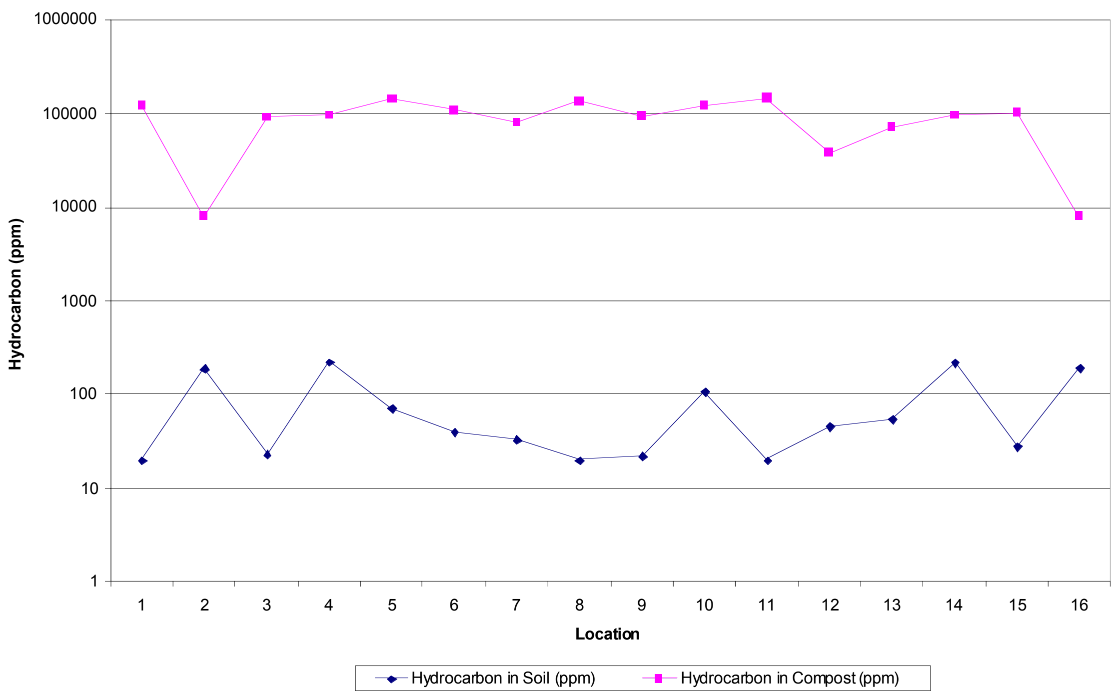

Figure 6. Hydrocarbon Content in Compost and Underlying Soil (Semi-Log)

Summary

Some of the characteristics of mature compost have been discussed in this paper. This paper has provided evidence to confirm that mature co-compost is non-toxic and non-leaching. The co-compost process is largely temperature independent.

The results of ongoing investigations generally show land applied mature co-compost meet applicable federal and provincial criteria. This includes meeting hydrocarbon and salinity closure criteria for receiving soils as defined in Guide 50 Drilling Waste Management, Alberta Energy and Utilities Board, October 1996.

Mature compost materials have been used for land reclamation on wellsites, access roads, and pipeline right of way's as well as other dispositions held by the mineral surface lease holder on public land.

In addition to overall soil quality improvement, the material has proven to:

- Minimize erosion;
- Improve aeration for compacted soils;
- Increase water retention for sandy / rocky soils;
- Sustain nutrient availability and interaction (increased C.E.C.) - Nutrient benefit for up to 8 years from typical applications.; and
- Facilitate associated fungal development to assist in re-building soil/vegetation on disturbed lands.

Given the limited waste management options currently available, co-composting is a practical and effective method for drilling waste management. The co-composting system defined in this paper generates a quality soil resource from petroleum impaired materials.

Acknowledgements

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References

1. U.S. EPA, Solid Waste and Emergency Response (5305W). An Analysis of Composting as an Environmental Remediation Technology. EPA 530-R-98-008, April 1998.

2. Rynck et. al. On Farm Composting Handbook. Northeast Regional Agricultural Engineering Service (NRAES-54). June 1992.

3. Danielson, R.M. (ed.) 1998. The Bioremediation Manual: A User's Guide to the Remediation of Salt- and Hydrocarbon-Contaminated Soils. Canadian Association of Petroleum Producers, Publication #1998-0003, December 1998. Calgary, Alberta. 131 p.

4. U.S. EPA Office of Special Waste SW-846. Test Methods for Evaluating Solid Wastes Physical / Chemical Methods – Method 1311.

5. Alberta Energy and Utilities Board. Guide 50, Drilling Waste Management, October 1996 Edition.

6. Canadian Council of Ministers of the Environment (CCME). Guidelines for Compost Quality (CCME 106 E). March 1996.

7. Environment Canada. Biological Test Method: Toxicity Test Using Luminescent Bacteria (Vibrio fischeri), EPS 1/RM/24. 1992b.

8. American Society of Testing and Materials. Standard Guide for Conducting a Laboratory Soil Toxicity Test with Lumbricid Earthworm Eisenia foetida, E1676-95, ASTM Vol. 11.05. 1996a.