Composting: A Biotreatment Process for Hydrocarbon Contaminated Drilling Wastes

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ABSTRACT

Selecting an appropriate method for disposal of hydrocarbon contaminated drilling waste involves a number of fundamental issues; regulatory compliance, environmental risk and liability, cost effectiveness, environmental impact, and timeliness of disposal.

Newpark's composting process was developed as a viable bioremediation option for management of drilling wastes generated from oil based mud systems. Hydrocarbon contaminated drill wastes are blended with programmed organic substrates and nutrients, with the mixture being constructed into on-site compost windrows. By providing an optimum environment, including moisture, aeration, nutrients and secondary treatment enhancers; Newpark's composting protocol allows for enhanced degradation throughout the entire year, even at –50 ^{o}F.

The material is managed to maintain optimum bio-degradation levels until the hydrocarbon levels have reached suitable levels for final land application. The compost material is then assessed for toxicity prior to land application; to date Newpark's compost material has been exposed to and consistently passes all bioassay procedures. In addition, these compost materials consistently meet with commercial compost quality criteria.

Newpark's composting process is not only an effective method of hydrocarbon contaminated waste treatment, but the resulting media is a highly organic, nutrient rich, value added product. The material is used to provide soil erosion control, nutrient benefit, improved tilth, and overall enhanced reclamation of disturbed soils on the well site or leased areas.

INTRODUCTION

The year 2001 drilling season will generate in excess of 500,000 cubic yards of oily drilling waste in Western Canada alone. The petroleum hydrocarbon contamination issue is further illustrated by several hundred thousand tonnes of contaminated soils seen annually throughout our region.

Management options for these contaminated materials include the following:

- Landfill Disposal
- Landfarming / landtreatment systems
- Encapsulation / stabilization
- Thermal Destruction or recycling
- Washing and recovery systems

Landfill storage 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. Typically, a bioremediation treatment system will falter in its ability to meet financial goals or closure requirements. In addition, many bioremedial methods perform poorly in our generally difficult Canadian climate.

In the past, land treatments were the mainstay of 'in-field' bioremediation systems throughout Western Canada. 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 best answer and were becoming less attractive to our clients. Operators were looking for solutions to the restrictions imposed by land treatment systems; timely management, large land disturbances, aggravation of native soils, and potential reclamation difficulties. Composting systems that require a smaller footprint, work in extreme environmental conditions, and provide accelerated biodegradation have shown great promise in the treatment of the drilling wastes generated from oil based mud drilling, and are now moving to become a mainstream option.

COMPOSTING 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. These compost temperatures follow a predictable pattern as the process evolves with spikes and drops impacted by aeration events and internal conditions. (Fig. 1)

In the past 15 years, composting technology has developed as an excellent remediation and land reclamation tool. 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.

WASTE VS. BENEFICIAL PRODUCT

A waste is simply a material for which there is no re-use or recycle value. Certain technologies are able to convert waste materials into value added commodities. Composting is such a technology, with regards to biodegradable organic wastes. Increased scrutiny on waste management, shrinking landfill space, and reduction in suitable soil resources, has brought composting to the forefront of waste management and conversion strategies. Backyard, mixed source waste (MSW), agricultural, and industrial composting systems are rapidly becoming the cornerstone of landfill diversion systems.

Our capital city (Edmonton, Alberta) has taken the initiative with the TransAlta composting facility, observing a 35% waste diversion within the municipal waste disposal system. As understanding of biological treatment techniques improves there is an increased acceptance of the waste conversion process and resulting products. Composting techniques applied to oily wastes may provide similar benefits, whereby residual hydrocarbon contamination is converted into stable organic matter.

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. The total carbon from the oily waste itself will not create the 'self heating' composting characteristics.

Wood fibre products are commonly acquired through local forest product producers (e.g. Sawmills), where that material is commonly a waste material. 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.

Newpark developed custom composting products in order to provide optimal nutrient levels and enhanced rates of biodegradation. The **ProActivate** products (I, II, & III) provide ideal nutrient levels to ensure biological activity is limited only by available carbon. Programmed nutrient levels are kept at designated standards by balancing Nitrogen and Phosphorous with available carbon. Typical programs optimize available carbon to nitrogen at a 40:1 ratio, with phosphorous content at 1/10 that of nitrogen levels.

Probioxyl is a chemical surfactant designed to provide particle wetting capacity, structural enhancement, and stability to the compost system. 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.

COMPOSTING TREATMENT PROCESS

There are several fundamental 'conditions' required for effective biological remediation of petroleum hydrocarbons. Structural parameters, microbial quality, carbon type, macro & micro-nutrient levels, oxygen availability, moisture content, and trace elements must be balanced with the remedial method to optimize degradation rates. The very nature of composting technology allows for near optimal ***aerobic*** biodegradation activity.

Traditionally, the oily drilling wastes may be stored in containment sumps or tanks during drilling, with clean-up operations beginning upon completion of drilling operations. The **Composting While Drilling** (CWD) system removes the need for containment sumps and tanks by initiating the composting process upon generation of the waste. The environmental technicians provide direction and supervision of on-site personnel to appropriately blend the materials and 'stockpile' initial compost media on location. This procedure significantly reduces waste storage requirements, prevents 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. Specialized compost monitoring technicians ensure that construction and amendment activities occur as programmed. The windrows are turned (aerated) and amended as required to ensure that oxygen levels, moisture content, and nutrients maintain optimal levels.

The heat released by organic metabolization is the secret to maintaining active degradation throughout the year. These self-heating piles are successful in the cold northern climates in North America, even with winter chills below –50 ^{o}F. This characteristic sets composting apart from biopiles, biocells, and land treatments; which have sharply reduced bioactivity at sub-zero temperatures. The composting treatment process (temperatures) follows precisely the same pattern as traditional composting. (Fig. 1) This is ideal, as much of the composting activity is at temperatures of 95 – 110 ^{o}F, which closely corresponds with optimal temperature ranges for hydrocarbon remediation[3]. By maintaining the accelerated biological degradation in all seasons, composting is able to reduce treatment duration significantly.

Compost bioactivity, TPH levels, moisture content, and nutrient levels, are monitored until the process is midway into the curing stage; which triggers closure assessment. During this period much of the available carbon has depleted and compost temperatures approach ambient air temperature. This stage triggers our assessment for residual hydrocarbons, compost maturity, and toxicity issues. We use the term maturity for this stage, as it correlates with traditional composting terminology. At maturity, the compost is deemed to be at (or near) treatability end-point whereby the further degradation of the residual hydrocarbons is not cost effective in a compost windrow format.

Mature compost will still maintain a residual hydrocarbon content. A common misconception with bioremediation is the belief that 100% of the hydrocarbon contaminant will be removed, unfortunately residual levels will remain in all treated product and levels will vary with the hydrocarbon type and treatment process. A properly managed compost treatment of diesel / mineral oil contaminated drilling waste should observe a 80 - 90% reduction in hydrocarbon content within the compost windrow. A further 5-10% reduction will occur in the final land application stage. (See pilot project)

Degradation rates for diesel, distillate, mineral oils, and similar products typically ranges from 300 – 500 mg kg^{-1} day^{-1} in the active phase with 100 – 200 mg kg^{-1} day^{-1} into the final stages of windrow composting. Newpark's composting program in Antigonish, Nova Scotia, manages synthetic oil contaminated wastes with degradation rates in excess of 700 mg kg^{-1} day^{-1}.

EQUIPMENT

Several compost mixing and 'turning' systems were trialed during the development of this procedure for oilfield drilling wastes. Agricultural mixers, modified spreaders, horizontal windrow turners, and ALLU's™ hammermill buckets were tested. Many of these systems provided excellent blending and mixing capabilities, however; most of these units failed in durability and were impractical for oilfield operations. Newpark selected the ALLU™ hammermill buckets due to suitability for working with oilfield construction equipment. The ALLU™ buckets can be retrofitted to conventional loaders and tracked hoes, which are readily available and accepted within the oilfield construction arena. The mixing rate may be somewhat reduced when compared with horizontal turning systems, but the units more than compensate in flexibility for pile size and tolerance to varied site conditions.

COMPOST STABILITY

Environmental impact from hydrocarbon migration is a serious concern with any waste management system. Land treatments, biocells, biopiles, landfills, static piles, and composting are all exposed to natural precipitation and possible release of hydrocarbons from the containment system.

Newpark's treatment program requires the use of a specialized surfactant (**Probioxyl**), which assists in providing stability of water:oil within the compost matrix. Multi-project data confirms the success of this method of 'maintaining' pile fluid stability. The climate in B.C. and many areas of Alberta does bring high levels of precipitation; as such, water management is an integral portion of our treatment program. In general, any leachate related fluids generated from our treatment piles are recycled through the compost matrix to provide the moisture required for optimum degradation. In extreme cases, the water may require removal from the treatment system. In these instances, the water is analysed and discharged observing the 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 2. The TCLP analytical procedure is designed to determine the mobility of contaminants present in liquids, solids, and multiphasic wastes(4). Briefly, this procedure oversaturates 1 part sample in 20 parts of mildly acidic water, and rolls the mixture for 24 hours. The fluids are then extracted and tested for the presence of any released contaminants, petroleum hydrocarbons in this instance. This study included analyses on all stages of the composting process with total hydrocarbon content ranging from 19,000 to 207,000 mg/kg. The oil content in the leachate was found to be very low at 0.1 to 26.5 ppm, with an average below 10ppm TPH in the extract. This equates to a mere fraction of the hydrocarbon content of the compost material itself. (Fig. 2)

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 provides excellent 'in field' containment of the hydrocarbon contaminants. The highest recorded hydrocarbon level in the actual leachates was 9.6 ppm, with typical results measured below 2.0 ppm.(Fig. 3) 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). Newpark's analytical assessments have shown our compost is unable to release petroleum hydrocarbons into water at any saturation level.

MATURITY AND TOXICITY TESTING

The composted product meets those release criteria set out for traditional drilling waste management, outlined in the Alberta Energy and Utilities Board Guide 50 document for Drilling Waste Management(5). However; more data was required to further utilize these materials as soil amendment beyond well site boundaries. A pleasant surprise from the composting system is the absolute ***non-toxic*** nature of the final product. Newpark's mature compost product has been exposed to, and passed, a battery of biological toxicity procedures. Likewise, each lot of compost is subjected to compost quality assessments along with an acute toxicity assessment. To date, on over 80 mature projects, we have exceeded the maturity criteria as defined for saleable compost; this is not to suggest a use of this product in residential gardens, but we do meet those standards[(6)]. With regards to trace elements (metals) over 95% of our compost meets CCME Category 'A' compost quality criteria (consumer grade), the remaining meeting Category 'B' standards (industrial grade).(Fig. 4) The low trace elements are not due to the composting process; but rather, good drilling fluid product screening by industry.

Ecotoxicity assessments routinely include the Microtox™ test (*Vibrio Fischeri*)[(7)] in conjunction with Radish (*Raphanus sativus*) and Cress *(Lepidium sativum*) germination and 14 day biomass measurement[(6)]. 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) Figure 5 & 6, illustrate some routine toxicity data collected on compost projects analysed at maturity in 1999 / 2000. Consistent Microtox™ non-toxic results, on all mature projects, is quite significant in this author's opinion, as this particular test is extremely sensitive to petroleum contamination.(Fig. 7)

Mature compost materials have been used for land reclamation on wellsites, access roads, and pipeline ROW's, as well as applied to agricultural lands. In addition to the soil quality improvement, the material has demonstrated excellent erosion control application.

PILOT PROJECT

Newpark began exploring alternatives to land treatments in 1996, with a full-scale pilot program beginning in 1997. The initial field program was developed in Petro Canada's Wildcat Hills field, west of Calgary, Alberta. Initial amendment blends were determined using composting cells / bins (1 yd^3). This stage of the technology assessment identified definite bioactivity and potential as an effective treatment system.

The Wildcat Hills pilot specifically managed and treated 620 cubic yards of oily solids (cuttings & centrifuge underflows) along with 435 cubic yards of oily liquids. Total Petroleum Hydrocarbon (TPH) was measured at 108,000 mg/kg within the initial compost media blend. This composting system was activated in the fall of 1997, the project was monitored and amended as required for one year. Hydrocarbon content was reduced by 75% within the first 150 days (Ie. 500mg kg^{-1} day^{-1}), with the compost maturity occurring by day 300. The mature compost contained 18,000mg/kg non-leaching, non-toxic, hydrocarbon residual.

Concurrent to the curing stage of the treatment process, an in-situ vegetation growth study was performed on the compost product. The compost materials were applied to the surface of disturbed soils adjacent to the wellsite activity area to determine impact to receiving soils. Several variables were incorporated into the growth trials including: Hydrocarbon content, fertilization, soil incorporation, and application rate. Figure 8 outlines the design of the compost material assessment.

Assessment of the growth trial plots indicated that the compost media improved vegetation growth, health, and erosion control characteristics of the receiving soil.(Fig. 9) The data gathered from the growth trials were utilized to gain approvals to surface apply the finished product to native soils surrounding the wellsite area.

Approvals were granted by Alberta Environment (AENV) and the Alberta Energy and Utilities Board (AEUB) to remove the material from the treatment area and surface apply to the disturbed soils adjacent to the 'cut and fill' areas surrounding the wellsite. Research requirements dictated that we applied the materials with no incorporation into the receiving soils, this allowed completion of the project with no impact from dilution with receiving soils. The site was seeded and allowed to re-vegetated in the spring / summer of 1999, with a final assessment of vegetation and residual hydrocarbons in September.

The TPH in the surface applied material was found to meet Guide 50 Drilling Waste Management criteria for release. The average TPH value at 681 total project days was 3707 mg/kg in the compost material. (Fig. 10)

Sampling and analyses of base and adjacent soils clearly showed there were no concerns with contaminant migration throughout the entire project. Annual inspections of the compost have noted excellent plant seed development, regeneration (I.e. lifecycle), and healthy native species encroachment. This project was profoundly significant for several reasons:

1) Activity footprint was under ½ acre and outside of wellsite activity areas,
2) Surface application provided erosion control and revegetation benefits to the disturbed soils surrounding the wellsite activity area.
3) The procedure demonstrated accelerated biodegradation rates.
4) There was **no dilution** impact from native soils, demonstrating successful management using the process alone.
5) Clearly proved that biodegradation was possible as a year-round process.
6) Demonstrated compost bioconversion as an excellent waste recycling tool.
7) Biodegradation in excess of 97% for the diesel contaminants. (Fig. 10)

Petro Canada's pilot project proved the effectiveness of this process and generated data allowing regulators to approve Newpark's process to continue as a viable option.

SUMMARY

Globally there has been a strong movement to divert organic matter from landfill disposal thereby preventing loss of soil resources; especially if there are suitable processes for re-use of these materials. This composting system has consistently demonstrated the ability to provide a quality soil resource from hydrocarbon contaminated drilling wastes.

This system is rapidly finding application throughout our industry, currently Newpark manages over 400 compost projects throughout Western Canada; as well as at our bioremediation facilities in Nova Scotia and Wyoming. Continued research is required to generate process specific closure criteria as designed for each petroleum hydrocarbon type. Newpark is also designing a composting system to address the bitumen contaminated drilling wastes generated in Alberta's oilsands region, initial pilot project data will be compiled by December 2001.

AKNOWLEDGEMENTS

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Figures Appendix

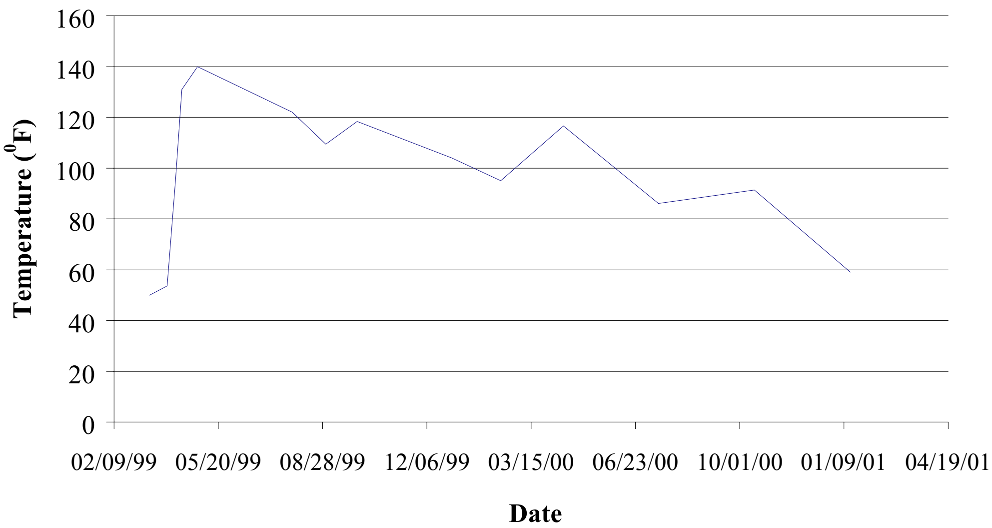


Figure 1. Internal temperature profile for a typical composting treatment matrix

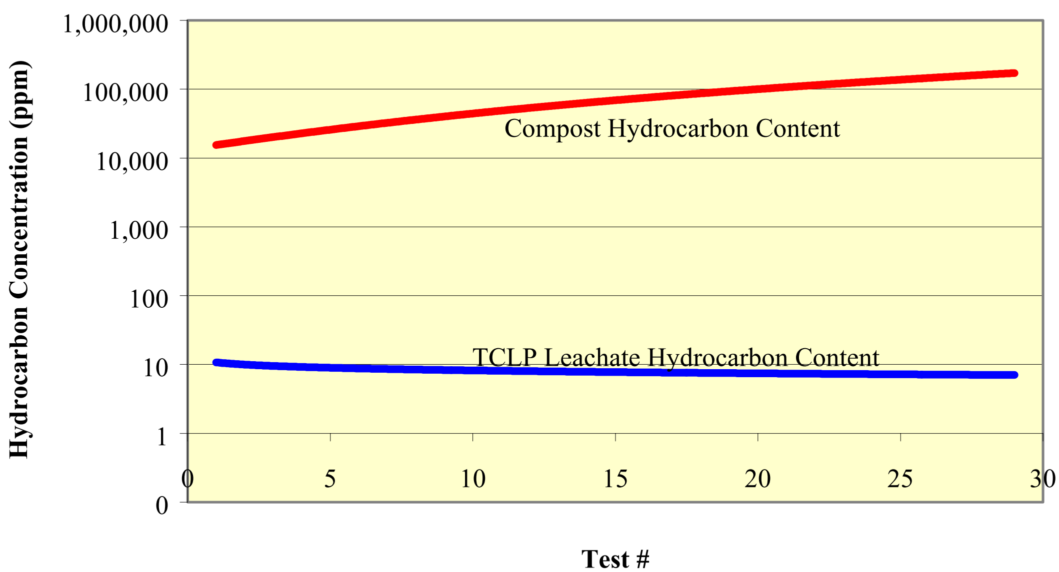


Figure 2. Laboratory TCLP hydrocarbon leachability study. (Semi-Log)

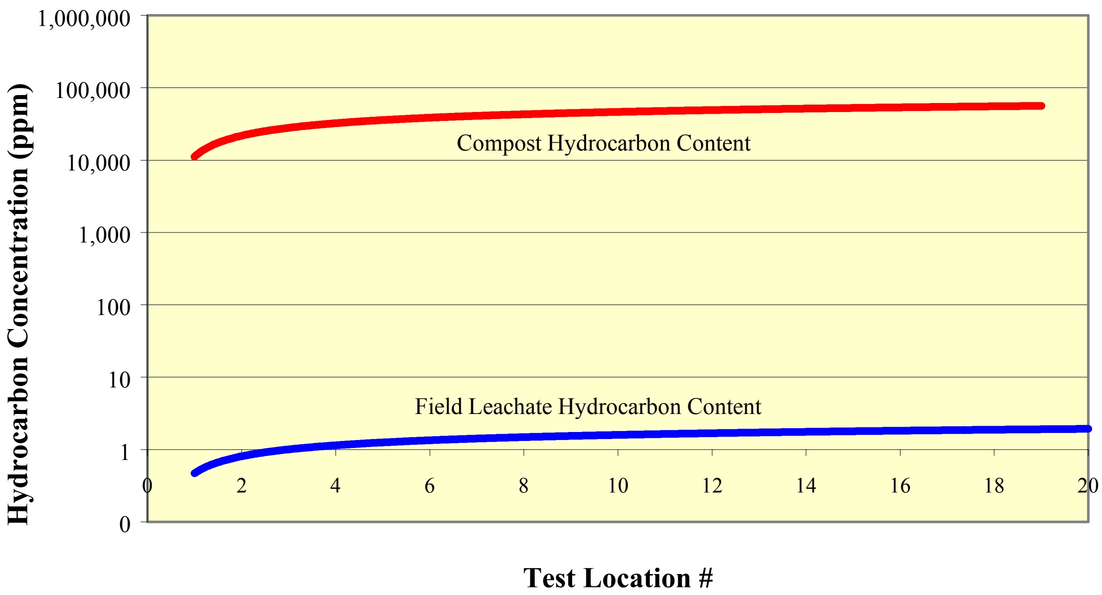


Figure 3. Leachate hydrocarbon content from Newpark treatment locations. (Semi-Log)

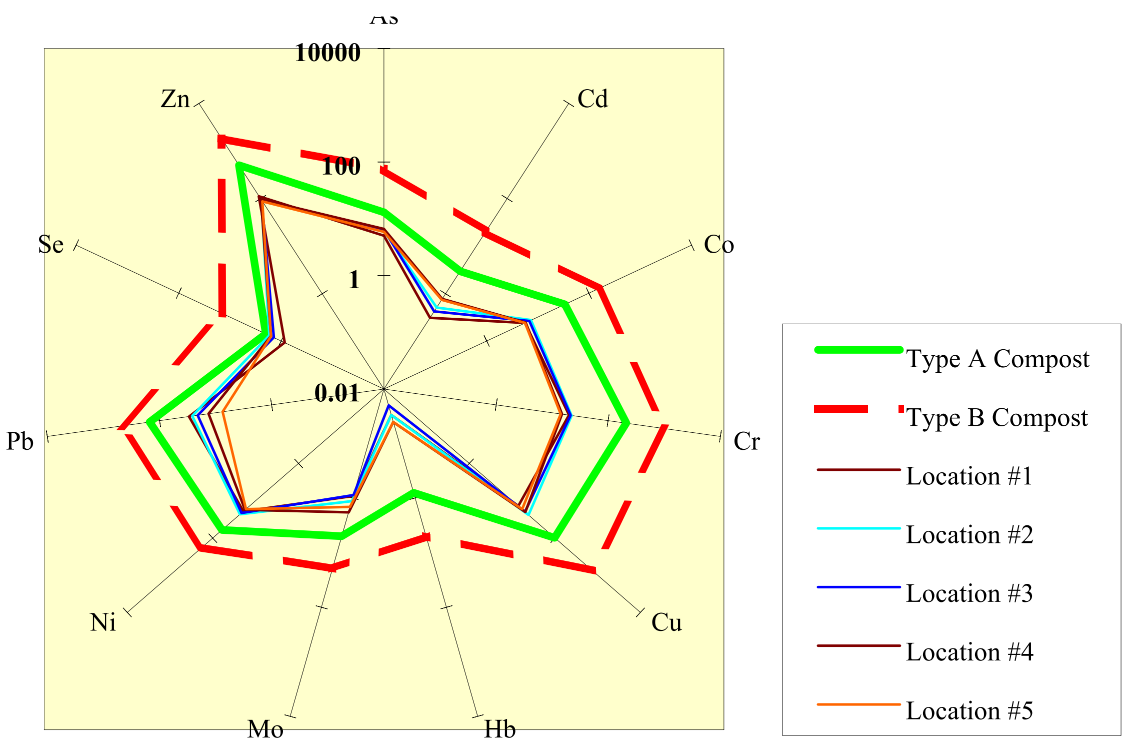


Figure 4. Trace elements (metals) as compared with national compost quality standards

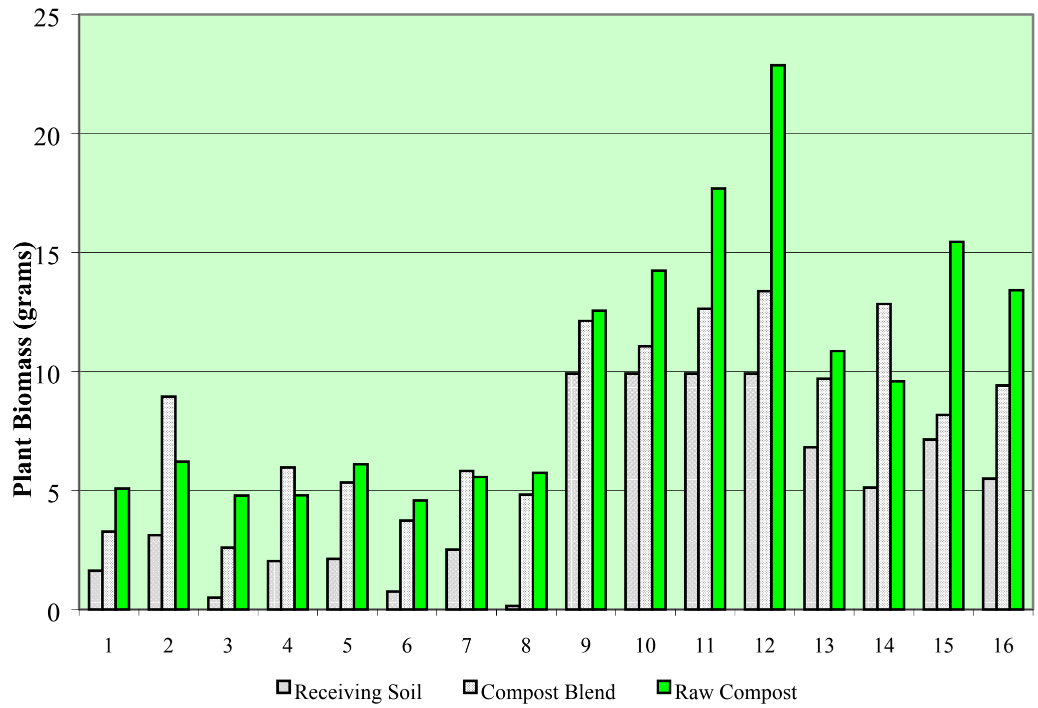


Figure 5. Radish biomass (14+ Days) 1999 closure locations.

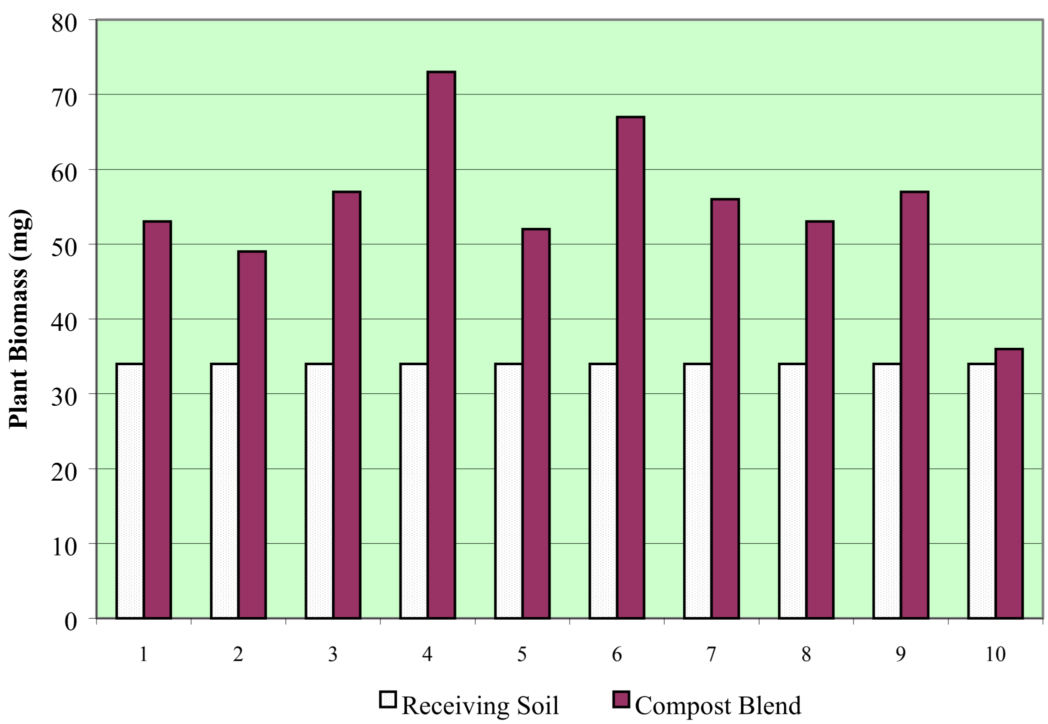


Figure 6. Cress biomass, April 2000 closure locations.

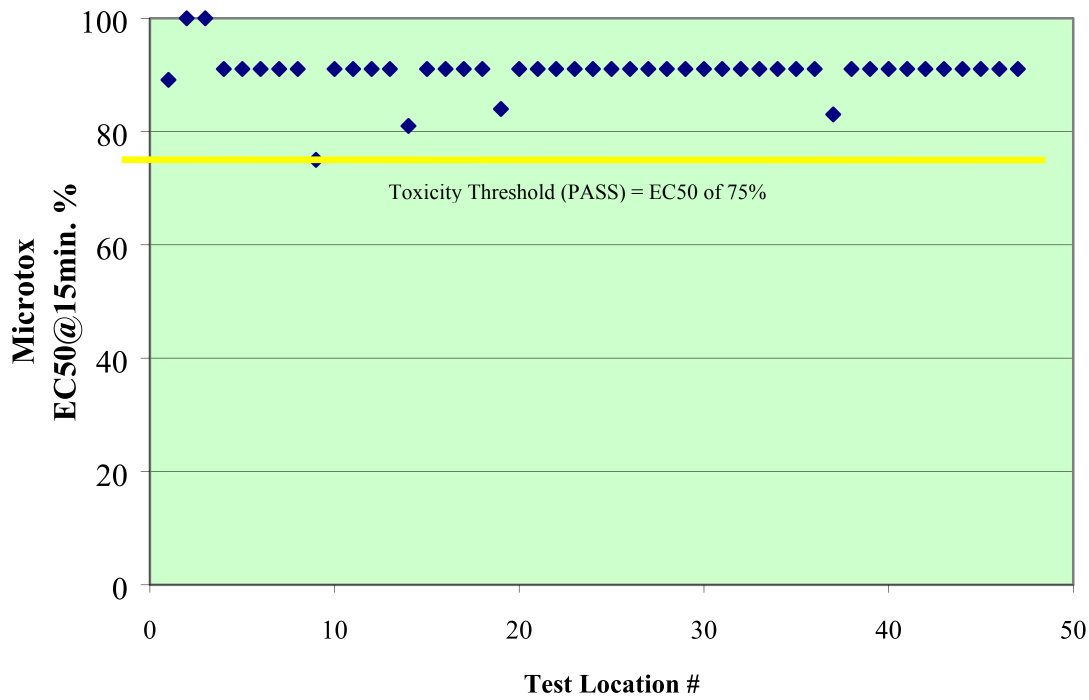


Figure 6. Microtox™ bioassay results (1999 / 2000 closure locations)

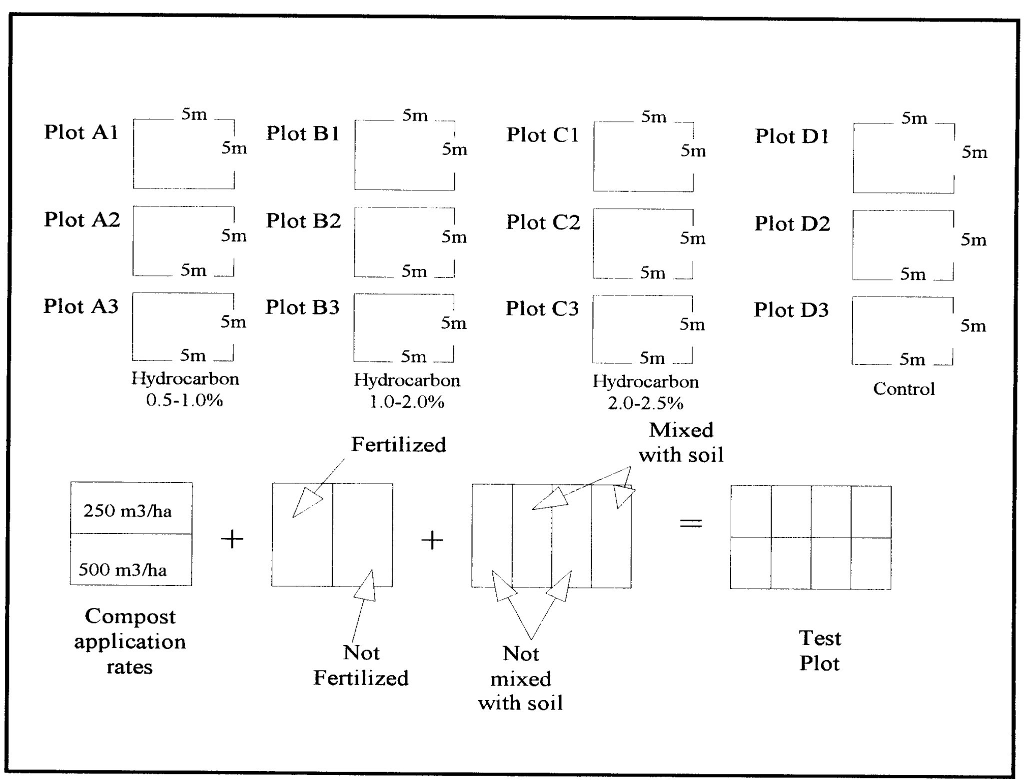
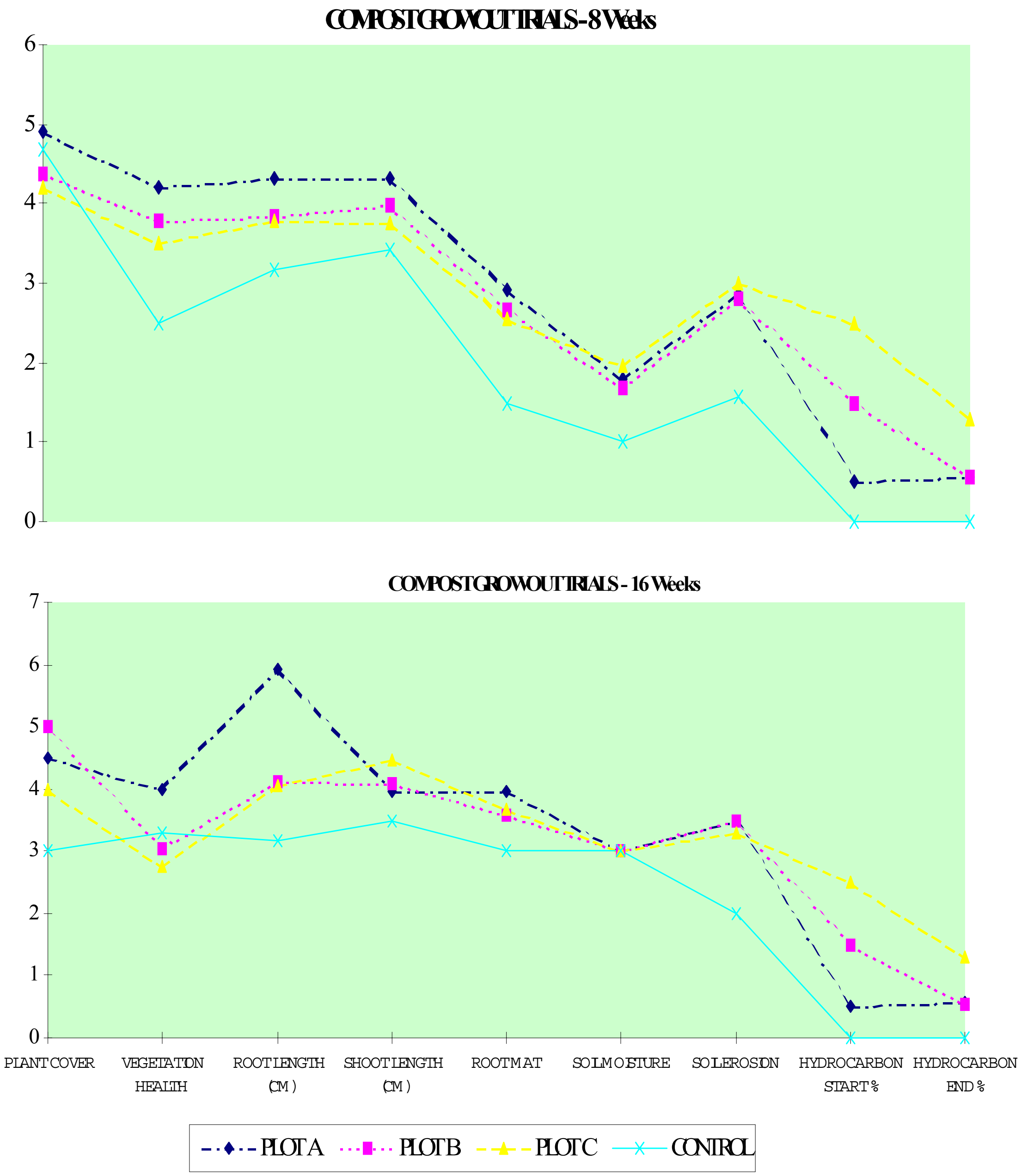


Figure 8. Vegetation growth trial plot design.



COVER CLASS	VEG. HEALTH	ROOT MAT	SOIL MOISTURE	EROSION CLASS
1=0-1%	1=Dead	1=None	1=None	1=Extreme
2=1-5%	2=Stressed	2=Minor	2=Minor	2=Moderate
3=5-25%	3=Typical	3=Moderate	3=Moist	3=Minor
4=25-50%	4=Above average	4=Strong	4=Saturated	4=None
5=50-75%	5=Exceptional	5=Exceptional		
6=75-95%				
7=95-100%				

Figure 9. WCH Pilot Project – Vegetation growth trial assessment

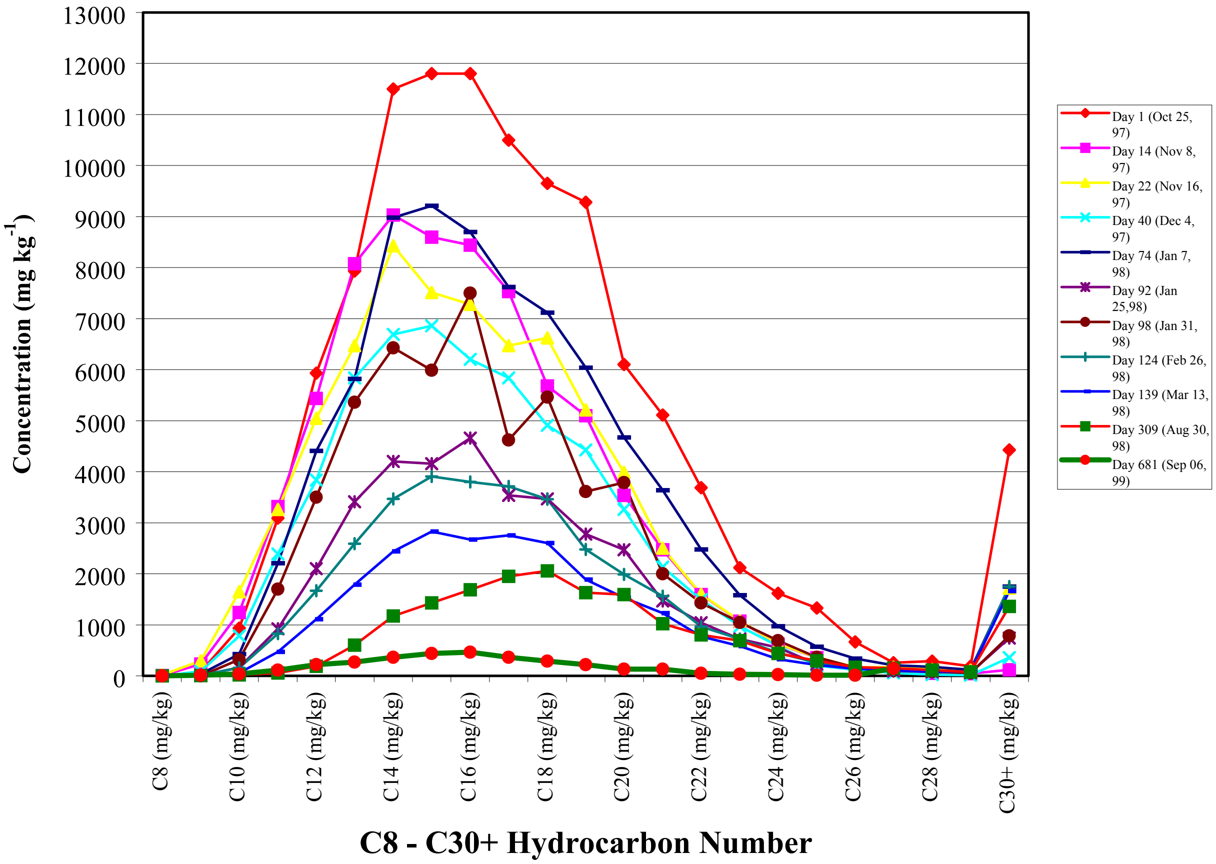


Figure 10. WCH Pilot Project – Hydrocarbon Content and Range