Biofarm Cell Operations & Maintenance (O&M) Manual

Report

February 26, 2003

Biofarm Cell Operations & Maintenance (O&M) Manual

Government of Nunavut

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Submitted by
Dillon Consulting Limited

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(In reply, please refer to)
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February 26, 2003

Government of Nunavut
Public Works & Services
Petroleum Products Division
PO Box 590
Rankin Inlet, Nunavut X0C 0G0

Attention: Mr. Baljinger Brar
Project Officer

Biofarm Cell Operations & Maintenance (O&M) Manual
Bulk Fuel Storage Facility, Taloyoak, Nunavut

Dear Mr. Brar:

Dillon Consulting Limited is pleased to provide you with six copies of the Biofarm Cell Operations & Maintenance (O&M) Manual for the facility designed to accept hydrocarbon contaminated soil from the Bulk Fuel Storage Facility located in Taloyoak, Nunavut.

We trust that this report meets your requirements, and look forward to your comments upon your review of this document. If you have any questions or require further information, please contact the undersigned at your convenience.

Yours truly,

Dillon Consulting Limited

Douglas D. Bell, M.Sc., P.Geo.
Regional Practice Leader
Site Contaminant Management
North/West Region

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Attachment

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1 INTRODUCTION

Dillon Consulting Limited (Dillon) was retained by the Government of Nunavut (GN), Public Works and Services (PWS), Petroleum Products Division (PPD), to develop an Operations and Maintenance (O&M) Manual for the biofarm cell facility designed to accept hydrocarbon contaminated soil from the Bulk Fuel Storage Facility in Taloyoak, Nunavut. This manual was developed as part of the report titled *Biofarm Cell Construction and Remediation of Re-supply Area Taloyoak, Nunavut* (Dillon, 2003), which identifies the biofarm cell design specifications, site selection and source of the contaminated material.

The remedial excavation and biofarm cell construction are a result of findings from two previous investigations, namely: *Phase I/II Environmental Site Assessment (ESA), Bulk Fuel Storage Facility, Taloyoak, Nunavut,* and; *Phase III ESA, Bulk Fuel Storage Facility, Taloyoak, Nunavut.*

This manual was prepared by Mr. Steven G. Martin and Mr. Martin Suchy, and was reviewed by Mr. Doug Bell.

1.1 Scope of Work and Objective

The scope of work of this project involves the aerobic treatment of soils contaminated with petroleum hydrocarbons of a diesel/heating oil variety. The objective of this manual is to define the O&M procedures specific to this biofarm cell operation.

1.2 Landfarming Technology Overview

Landfarming has been used at many sites across the Northwest Territories and Nunavut. This process relies on biological degradation and volatilization to remove hydrocarbon-based compounds. To implement the landfarming process, the soil is generally spread in a thin layer (0.15 m - 0.20 m deep) over an area, and then tilled on a regular basis to promote aeration and stimulation of microbial activity. If the soil thickness is increased the process will work equally well, however, the duration of remediation will also increase. Similar to ex-situ biopile remediation, nutrients, moisture and microbes may be added to accelerate the biological degradation of hydrocarbon impacted soils. In some instances, landfarming must be performed over an impermeable liner to prevent the migration of contaminants (leachate) into the underlying native soil and ground water.

1.3 Facility Description

The subject biofarm cell was constructed to accept hydrocarbon contaminated soil from the Bulk Fuel Storage Facility re-supply area. The cell is located near the local landfill, Lot 1000, LTO 1608. Design specifications required the cell to be surrounded by a gated 1.9 m zinc-galvanized chain link fence in order to accommodate equipment necessary for tillage activities. However, the fence was not erected as part of the September 2002 work program.

The cell is approximately 1.8 m in height and 33 m by 33 m in length and width respectively. The surrounding berm is constructed of recompacted native fill, and covered with an impermeable membrane that is keyed into the top of the berm on all four sides. The impermeable membrane is comprised of a 300 mm Arctic Liner® that is underlain and overlain by a 10 oz/yard Non-Woven Geotextile, and covered by 50 mm of fine granular material.

The slopes of the berm are 2.5:1 on the inside slope and 2:1 on the outside slope. A 1.1 m deep (3.5 m square) retention basin has been constructed in the western corner of the landfarm containment berm, and filled with fine granular material. A 100 mm High Density Polyethylene (HDPE) perforated leachate collection pipe is located at the bottom of the retention basin, connects to a solid pipe on the sloped face and runs to the top of the berm. The leachate collection pipe can be used to control moisture content by removing leachate or water from the retention basin and spraying back onto the contaminated soil (See drawings T1 and T2 for design specifications, cell plan and sections views).

Construction of the cell was completed on September 24, 2002 and filled with contaminated soil between September 24 and 26, 2002. The process was overseen by Jason Andrews, E.I.T. of Dillon.

1.4 Contaminated Soil Description

Remedial excavations of hydrocarbon contaminated material were conducted on two areas near the re-supply connection (see Drawing T1). The contaminated soil was excavated to the depth of the permafrost (approximately 1 m to 1.2 m below the surface), but was not removed within 45 degrees of structural footings. The excavated material was largely sand and silty clay, with pebbles and cobbles. Dark staining and varying strengths of hydrocarbon odour were noted in the excavated soil. The contaminated material was characterized during the Phase I/II ESA and Phase III ESA conducted by Dillon in 1999 and 2000, respectively. Total Petroleum Hydrocarbons (TPH) were detected in soil samples at concentrations as high as 3,400 ppm. Benzene, Toluene, Ethyl-benzene and Xylenes (BTEX) were not detected in the analyzed soil samples.

2 OPERATIONS AND MAINTENANCE PROCEDURES

Landfarming is a full-scale bioremediation technology that requires the excavation of soil and the use of liners to prevent the leaching of contaminants into underlying soils and ground water. Controlling the soil conditions to optimize the rate of contaminant degradation can be achieved by manipulating moisture, aeration, pH, nutrients and bacterial counts. The O&M procedures listed below will help to optimize the rate of contaminant degradation and prevent leaching of contaminants from the landfarm site. The attached Biofarm Cell Operation and Maintenance Site Checklist and Summary Checklist (Appendix B) should also be completed every time the site is visited. The checklist is to be used to record site conditions and activities during every site visit, and helps track to progress of biodegredation.

2.1 Health and Safety

A Health and Safety Plan should be developed to provide comprehensive protection against all known and potential hazards. Specifically, it establishes policies and procedures to protect workers and the public from potential hazards posed by the facility and its operation. A Health and Safety Plan describes the potential hazards at the site, identifies the personnel responsible for health and safety issues, and describes actions to be taken to mitigate the identified hazards.

Where appropriate, on-site safety procedures and equipment should be determined. This pertains to fire extinguishers, first aid kits, telephones/radios, and emergency mustering points. All workers are required to abide by the provisions of this plan. Every worker is required to be familiar with the contents of the plan and adhere to its principles and procedures.

2.2 Snow, Water and Leachate Control

The use of a snow fence on the contaminated soil is not recommended due to the accumulation of excess moisture in the springtime as a result of melting snowdrifts. Excess moisture may facilitate movement of contaminated leachate and water runoff from the containment berm. Minimal amounts of snow should be allowed to accumulate to prevent movement of leachate from the containment berm.

Preventing the movement of contaminants out of the containment berm is imperative. The most critical time is in late spring early summer, when accumulations of snow are melting within the berm. Water collected within the berm should be inspected on a weekly basis during periods of snowmelt, and evaluated as to whether there is a possibility of overflow. If the water level within the containment berm is such that overflow is occurring or is imminent, the following actions should be undertaken:

The leachate collection pipe at the west end of the containment berm should be inspected to determine if hydrocarbon leachate is present at the base of the retention basin.

If leachate is present, water from the pooling area should be pumped into temporary holding tanks such as used 205 L drums or other available tanks. Enough water should be pumped out to stop the berm from over-flowing without emptying it.

If only clean water is present, then a sump pump suction hose should be placed into the water-filled trench at the freeboard of the berm, pumping water outside of the berm and onto the ground surface. Enough water should be pumped out to stop the berm from over-flowing without emptying it.

If no danger is identified, the state of the frozen contaminated soil should be observed and evaluated to commence the summer tilling process. The potential for leachate build-up in the collection pipe should be inspected on a monthly basis once tillage begins.

2.3 Aeration (Tillage)

The containment within the landfarm does not have a cover or shelter of any kind. This allows access to the soil for tillage purposes, increasing microbial activity and biodegradation of contaminants.

After the ground surface has completely thawed, it is recommended that the soil be tilled approximately every three to four weeks (for a total of five times per season) in order to aerate the soil. Tilling of the contaminated soil should continue until average daily temperatures drop below zero degrees Celsius. This will allow the soil microbes that degrade hydrocarbon contaminants to mix thoroughly in the soil, facilitate gas exchange, and increase the rate of metabolism of contaminants.

Early tillage of the soil (as soon as the soil has partially thawed) will increase the temperature of the soil, in addition to providing aeration. This will increase soil microbe activity for biodegradation of soil contaminants.

2.4 Temperature

Temperature has an affect on the biodegradation rates associated with hydrocarbon contaminated soil. Due to the design of a landfarming facility (relatively thin soil; approx. 1 m), soil temperature will vary due to daily and seasonal fluctuations. However, due to the extended daylight hours in Taloyoak, soil temperatures should remain quite stable during the summer period. Microbial degradation rates are expected to double with every 10°C increase in temperature (Gunnison and Vicksburg, 1991). Soil temperature may be monitored and recorded using a standard glass thermometer inserted in to the soil.

2.5 Soil pH

PH is often used as a guide for the diagnosis of a soil. A soil's pH may influence the bioremediation process since soil microorganisms require a specific pH range to survive. Most bacteria function in a pH range between 5 and 9, with the optimum being slightly above 7 (Dragun, 1988). Very few soils will require dramatic adjustments of their pH. However, if soil pH drops below 5 (i.e., becomes acidic), crushed limestone or agricultural lime should be added. If the soil becomes too basic, sulfur, ammonium sulfate, or aluminum sulfate may be added during the next tilling even to maintain a neutral pH (i.e., close to 7).

Soil pH should be monitored twice a year (once each at the beginning and end of the summer months) following a regular tilling event. Soil pH is best monitored using field pH strips.

2.6 Moisture Control

Microorganisms require moisture to transport nutrients, to carry out metabolic processes, and to maintain cell structure. However, excessive moisture in soil is undesirable because: (a) oxygen availability is reduced by the high fraction of soil pore space occupied by water molecules, and (b) excess moisture increases leaching of contaminants and nutrients from the soil. Ideally, moisture content is considered optimal between 10 and 20% by weight for aerobically bioremediating soils (King et al., 1992).

Due to the extended hours of sunlight during arctic summers, the moisture content of the soil should be inspected during regular tillage events, or more frequently if necessary, to ensure that an optimal moisture content range is achieved. It is likely that the moisture content of the soil will decrease as the remediation proceeds.

The retention basin and leachate collection pipe should be used to control the moisture content within the berm. When the landfarm soils begin to dry, any leachate and/or water from the retention basin can be sprayed back onto the soil to increase moisture content. If water is not available from the retention basin, a water truck can be used to add moisture while tilling is occurring. Increasing moisture is best done by spraying water onto the soil at the same location and time as the tilling activity.

2.7 Nutrient Control

The three (3) principal nutrients necessary for effective bioremediation of hydrocarbon contaminants are carbon, nitrogen, and phosphorus. The ideal carbon to nitrogen to phosphorus (C:N:P) ratio should be 120:10:1 (Bryant, 1998). The contaminants and natural organic compounds in the soil typically provide an adequate amount of carbon for successful biodegradation, however, the availability of nitrogen and phosphorus may often be insufficient in comparison. This can be rectified through the application of fertilizers such as Ammonium Nitrate and Superphosphate® during the first and fourth tillage events.

This will help to increase the activity of the soil microbes that biodegrade soil contaminants by supplementing the nutrient source required for growth. The process of applying fertilizer over a period of two tillage events satisfies the optimal C:N:P ratio of 120:10:1, yet maintains nitrogen and phosphorus levels that are low enough not to be considered toxic to soil microbes. Although nitrogen containing Urea® (46:0:0, N:P:K) has a greater nitrogen weight fraction that Ammonia Nitrate and is available in slow-release polymer coated pills, it is not recommended for use on this project since the minimum required nutrient release temperature is approximately 10°C (thus limiting its effectiveness in colder months). The following table identifies nutrient sources, ratios and quantities that should be used:

Nutrient	Source	Bag Size	Weight Fraction	Nutrient Required	Total Bags	Bags/Tillage
Nitrogen	Ammonium Nitrate	25 kg	0.34	275 kg	33	17
Phosphorus	Superphosphate	25 kg	0.27	27.5 kg	4	2

A nutrient solution can be mixed using water and the indicated number of bags of each nutrient. The solution can be mixed in a 205 L drum, and sprayed onto the soil using a pump and hose during the tillage events. No more than three (3) bags should be mixed per 205 L of water. The process should be repeated six times for each tillage event. Water should be obtained from the collection basin, or from external sources such as a water truck.

The addition of nutrients should be conducted twice during each of the first and second summers, and should be in excess of the minimum 120:10:1 C:N:P ratio since a portion of the added nitrogen and phosphorus will not be biologically available to the soil microorganisms.

A total of 66 bags of Ammonium Nitrate (25 kg) and eight bags of Superphosphate® (25 kg), will be required for two years of operation. *It is critically important that these bags not be left outdoors. The bags need to be stored in a dry environment, preferably off the ground on wooden pallets, and separated from each other.*

2.8 Hydrocarbon Contaminant Monitoring

The hydrocarbon status of the soil should be tested annually to assess the efficiency of the remediation plan. Soil samples collected from contaminated material should be collected no later than mid September, during the tilling process. At this time, ambient air temperatures will still be such that vapour headspace readings are representative of contamination levels.

Samples should be collected from a depth that represents the centre of the material, and should be of a homogenous nature. Each sample taken should be split in two; one half placed into a re-sealable plastic bag, the other half into a laboratory prepared 125 ml glass jar with a Teflon lined lid. The jarred sample is to be placed on ice in a cooler pending possible laboratory analysis, and the bagged sample is allowed to warm for approximately 10 minutes prior to field screening for volatile organic vapours using a Gastech Tracetechtor - Model 1238 (Gastech) combustible gas detector operated in methane elimination mode.

Prior to field use the Gastech must be calibrated using hexane at two points: 400 parts per million by volume (ppm) and 40% of the lower explosive limit (LEL). Volatile hydrocarbon vapours are measured using a fixed-volume headspace technique, in which the bagged soil sample is punctured and the headspace hydrocarbon vapour levels measured. The highest headspace vapour level observed is recorded in ppm or % LEL, as appropriate. For report consistency, headspace vapour levels recorded in % LEL are to be converted to ppm by multiplying by 100. The soils can be adequately characterized by collecting 15 samples, evenly distributed throughout the containment berm, and field screened using the above-mentioned techniques. Based on measured headspace vapour concentration, appearance and odour, three soil samples are to be submitted to a certified laboratory for analysis of hydrocarbon constituents.

Samples are to be collected by hand using single-use nitrile gloves for sampling quality assurance. Soil samples are also to be analyzed for moisture, pH, TPH, nitrogen, and phosphorus.

3 SUMMARY

Dillon was retained by the Government of Nunavut (GN), Public Works and Services (PWS), Petroleum Products Division (PPD), to develop an Operations and Maintenance (O&M) Manual for the biofarm cell facility designed to accept hydrocarbon contaminated soil from the Bulk Fuel Storage Facility in Taloyoak, Nunavut. This manual was developed as part of the report titled *Biofarm Cell Construction and Remediation of Re-supply Area Taloyoak, Nunavut* (Dillon, 2003), which identifies the biofarm cell design specifications, site selection and source of the contaminated material.

Bioremediation of the hydrocarbon-contaminated soils within the constructed cell will require a combination of soil management strategies including snow removal, tillage, irrigation, moisture monitoring, fertilization, pH control, leaching control, and hydrocarbon monitoring. Utilizing the protocol outlined in this manual will help to optimize the rate of biodegradation of soil contaminants in the cell. The following table summarizes all activities, which need to be undertaken during the minimum first two years of the facility operations. The attached Biofarm Cell Operation and Maintenance Site Checklist and Summary Checklist (Appendix B) should also be completed every time the site is visited to track progress within the cell.

Landfarm Operations and Maintenance: Procedural Checklist

Procedure	When	Action	Frequency
Health and Safety	At the beginning of every season:	Site personnel should conduct a review of the Health and Safety Plan. All personnel should review and understand the site hazards, understand actions to be taken to mitigate hazards, actions to be taken in case of an emergency, and know the locations of safety equipment.	Once per year
	During summer operations:	Understand site hazards, and check proper operation of safety equipment.	Every time on site
Snow, Water and Leachate Control	Just prior to spring thaw:	If excess snow accumulations have occurred within the berm, snow removal will be conducted to minimize the potential of the movement of water/leachate from the berm.	Once per year
	During spring thaw:	Check and record water level within the berm and degree of soil thawing	Twice per month
	During summer operations:	Check and record water level within the berm and check for leachate in soil retention basin.	During tillage activities
Tillage	When soil is thawed (June to September):	Thoroughly turn over soil to a minimum depth of 1 meter, or to the minimum depth of the buffer layer protecting the underlying liner, whichever is less. If the buffer material is encountered during tillage, adjust tillage depth accordingly.	Every 3 to 4 weeks, for a total of 5 times per season.

Landfarm Operations and Maintenance: Procedural Checklist

Procedure	When	Action	Frequency
Soil pH Control	During summer months (June to September):	Check and record soil pH using soil pH kit (should be between 5 – 7). If below 5 add lime.	During first tillage and fourth tillage events.
Moisture Control	During summer months (June to September):	Check and record soil moisture using probe. Make visual observation, (dry/damp/moist wet). Soil should be moist.	During every tillage activity
Nutrient Control	During summer months (June to September)	Mix nitrogen and phosphorus nutrients as required in 205 L drum, add water and spray onto soil.	During first tillage and fourth tillage events.
Hydrocarbon Monitoring	During summer months (August)	Collect and field screen 15 soil samples from soil volume; submit 3 samples of laboratory analyses for moisture, pH, TPH, nitrogen and phosphorus. Record hydrocarbon vapour emission field screening results.	During fourth tillage event.

It is recommended that operations at this biofarm cell be conducted for a minimum of two years, after which the analytical results can be evaluated, and a future course of action be determined. A total of 66 bags of Ammonium Nitrate (25 kg) and eight bags of Superphosphate® (25 kg) will be required for two years of operation.

It is critically important that these bags not be left outdoors. The bags need to be stored in a dry environment, preferably off the ground on wooden pallets, and separated from each other.

4 CLOSURE

This report was prepared exclusively for the purposes, project, and site location outlined in the report. The report is based on information provided to, or obtained by Dillon as indicated in the report, and applies solely to site conditions and the regulatory and planning frameworks existing at the time of the site investigation. Although a reasonable investigation was conducted by Dillon, Dillon's investigation was by no means exhaustive and cannot be construed as a certification of the absence of any contamination from the site. Rather, Dillon's report represents a reasonable review of available information within an established work scope and schedule.

This report was prepared by Dillon for the sole benefit of the Client and is not to be relied upon by any other party without Dillon's express written consent. The material in it reflects Dillon's best judgement in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibilities of such third parties. Dillon accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We trust this submission meets your requirements. If you have additional questions please contact the undersigned at your convenience.

Respectfully submitted,

Dillon Consulting Limited

Douglas D. Bell, M.Sc., P.Geo.
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