

New York State Department of Environmental Conservation

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This document was developed to provide Department staff with guidance on how to ensure compliance with statutory and regulatory requirements, including case law interpretations, and to provide consistent treatment of similar situations. This document may also be used by the public to gain technical guidance and insight regarding how the department staff may analyze an issue and factors in their consideration of particular facts and circumstances. This guidance document is not a fixed rule under the State Administrative Procedure Act section 102(2)(a)(i). Furthermore, nothing set forth herein prevents staff from varying from this guidance as the specific facts and circumstances may dictate, provided staff's actions comply with applicable statutory and regulatory requirements. This document does not create any enforceable rights for the benefit of any party.

Many procedures used by the Division of Environmental Remediation are undergoing revision as a result of our continual efforts to improve program implementation. In many cases, previously issued guidance documents are no longer completely consistent with current practice, but are provided here in their original form until final revisions are issued. Users of the posted guidance documents are urged to contact the Division of Environmental Remediation.

Spill Technology and Remediation Series (STARS) # 2

**Biocell and Biopile Designs
for
Small-Scale Petroleum-Contaminated Soil Projects
(Last Revised, May 1996)**

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BACKGROUND AND APPLICABILITY

As the number of petroleum-contaminated sites requiring cleanup in New York State increases, so does the desire for better, faster and more cost-effective ways to investigate and remediate these sites. This situation becomes more significant as the option of landfilling petroleum-contaminated soils decreases as more landfills close. As a result, landfilling becomes more costly for the few which remain in operation. Landfilling also brings with it the liability of stored petroleum-contaminated soil as well as the transfer of contaminated material from one location to another.

The New York State Department of Environmental Conservation (NYSDEC) Division of Spill Management (DSM) is concerned that the Responsible Parties (RPs) get their money's worth so they will continue to be responsible and cooperative in remediating petroleum releases to the environment. In addition, DSM wants to control expenditures from the New York State Spill Fund, which is a revolving fund of State and federal money used to investigate and remediate spills when an RP is unidentifiable, or is unwilling or unable to perform the work deemed necessary by DSM. The New York State Department of Environmental Conservation (NYS DEC) has been investigating and encouraging reuse and recycling alternatives to landfilling, which are efficient, cost-effective, and environmentally-protective. 6 NYCRR Part 611 refers to guidance that encourages recycling or on-site treatment versus disposal.

DEC has also been seeking alternatives which lend themselves to the development of a generic design approach for small-scale projects. Generic approaches are desirable because they could reduce the time lag and the overall costs of a spill cleanup for small-scale projects, by providing the preliminary design work for an (RP) or contractor to adapt to similar projects and by minimizing (or virtually eliminating) the engineering design phase. Generic approaches could also help educate RPs and contractors who do not have knowledge and experience in innovative remedial technologies.

Ex-situ (aboveground) bioremediation has been developed as a generic design approach for small-scale projects. This was possible because aboveground soil bioremediation technology can be adjusted to address soil type, contaminant type, soil quantity, and concentration.

Bioremediation creates and maintains a favorable environment to stimulate microorganisms to use contaminants (hydrocarbons) in soil as a food source. Under proper conditions, microorganisms, can break down contaminants into non-hazardous inorganic substances. Small-scale bioremediation lends itself to a generic design approach because the design criteria, which include moisture content, temperature and pH of the soil, can be simply measured and adjusted to optimum conditions for the process. The additional design criteria, nutrient and oxygen requirements, can be estimated based on contaminant concentrations in the soil. It is understood that generic parameters established by a standardized method may not provide the same remedial efficiencies as those based on a site-specific feasibility study; however, it is anticipated that the results will be adequate for small-scale projects.

The advantages of bioremediation include the following:

- ? it can be conducted on site,
- ? the waste is permanently eliminated,
- ? capital costs for these small-scale applications are cheaper than other processes,
- ? there is positive public acceptance because it provides for recycling,
- ? the long-term liability risks associated with leaving contamination on site are eliminated,
- ? there is minimum site disruption,
- ? transportation costs and liability of landfilling are eliminated, and
- ? it can be coupled with other treatment techniques.

Disadvantages of bioremediation include the following:

- ? the design criteria for highly efficient remediation are site-specific, and
- ? extensive monitoring may be necessary.

This design approach uses indigenous microorganisms applied to petroleum-contaminated soils of approximately 30 - 100 yd³, typical of the removal of an underground storage tank. This volume of soil was chosen because it should reduce costs for many RPs who do not have the resources to hire professionals with experience in bioremediation. In addition, it would reduce project duration time compared to less active approaches, and it would be a manageable quantity of soil for application of a generic design approach. The

same principles can be used for smaller or larger quantities. A less elaborate design would be appropriate for smaller quantities, and an experienced professional consultant is recommended for larger quantities.

The generic biocell and biopile designs are intended to provide an overview and direction to spillers on the use of ex-situ bioremediation of small-scale (approx. 30 - 100 yd³) petroleum-contaminated soil. While this document does not establish standards, it is intended as guidance to regional spill investigators and RPs for designing bioremediation cells and piles.

BIOREMEDIATION TECHNOLOGY

Bioremediation consists of creating and maintaining a favorable environment for microorganisms, either indigenous (naturally existing) or non-indigenous (brought in from another site), to use contaminants in soil as a carbon food source. The basic requirements for bioremediation to occur include a food source (hydrocarbons), oxygen, and nutrients (phosphorous and nitrogen), in a compatible environment (proper pH, temperature and moisture.) Other nutrients such as potassium, calcium, iron, manganese, cobalt, copper, and zinc, are generally present in adequate concentrations in most soil and aquifer systems, and usually need no further attention in the design of a bioremediation process.

Two commonly used designs for ex-situ bioremediation are the biocell and the biopile. In a biocell, the contaminated soil is spread in 1 to 2-foot layers. In a biopile, the contaminated soil is mounded in 3 to 4-foot piles.

pH

Petroleum-consuming microorganisms grow best at pH near 7. Where high concentrations of volatile compounds are present and where soils have low alkalinity (acidic conditions, i.e., $\text{pH} < 7$), liming may be necessary. Adding enough lime to attain a pH of 7.2 to 7.5 should be sufficient to maintain appropriate pH throughout the life of the project without having to monitor the pH. The lime added should be in the form of ground agricultural limestone (CaCO_3), similar to pelletized limestone sold in garden stores. Ground limestone is recommended because it is less expensive than other forms and applying excessive amounts will not affect treatment. Soil samples can be collected and taken to a local garden store for pH measurement and liming requirements to achieve pH near 7.

The pH of alkaline soil ($\text{pH} > 7$) should be reduced by the acidic by-products generated from the biological activity in the soil. As biological activity and resulting pH reduction continue, monitoring may be necessary to determine if acidic conditions occur and subsequent liming is necessary. For a project of this size and duration, pH monitoring may not be necessary after measuring and adjusting at the start of the project. As a conservative approach, pH could be measured once per season.

Note: Some studies have reported that lime may be harmful to hydrocarbon-degrading bacteria and magnesium sulfate may be used as a substitute. Since magnesium sulfate is apparently difficult to obtain, and since DSM has limited data discouraging the use of lime, DSM will continue recommending its use. Further investigation of the use of lime for pH control is recommended in a project where pH control is a concern.

Temperature

The microorganisms will operate best at ambient temperatures between 40° and 100°F. The heat generated by covering the soil, and from the biodegradation reactions should allow operation of a bioremediation process in most of New York State for approximately 9 months per year. Efficiency will improve as temperature rises and petroleum hydrocarbon degradation does not generate enough heat to be concerned with excessively high temperatures.

Covering piles will help to sustain heat. Black polyethylene covers are generally more durable than standard polyethylene, and will absorb heat to keep the pile warm. Clear polyethylene degrades more rapidly due to exposure to weather and sunlight. Therefore, to prolong the life of bioremediation processes in the Northeast, the use of black polyethylene covers is recommended.

Moisture

Moisture content should be maintained at 50-60 percent field moisture capacity, which means that the soil should be wet but not puddly. (Values of field moisture capacity for various soil textures are tabulated in the appendices of the original design paper.) If desired, moisture can be measured regularly using a lysimeter, monitored visually, and added as necessary. However, for this simple approach, moisture can be added using a spray applicator, and distributed in the cells by the weekly tilling process, or by natural dispersion through the piles. If spraying is not expected to provide enough moisture throughout a pile, then moisture could be added through a system of slotted pipes woven through the pile, to ensure even distribution.

Dechlorinated water must be used for bioremediation because chlorine can kill the microorganisms. In addition, the water must be potable quality water to avoid propagation of pathogenic bacteria during the bioremediation process.

If too much moisture is present in the soil, leachate may collect in the sump areas of the cells or piles. This leachate must be disposed of properly in accordance with local State and federal regulations. Depending on the level of contamination, disposal options may include discharging to a municipal sewer system with prior approval from the sewage treatment plant owner/operator, or to a regulated disposal facility. An acceptable alternative is to re-use the leachate for moistening the cells or piles. If there is more leachate than is needed, the excess must be properly disposed of, as described above.

Nutrient Requirements

Microorganisms degrade hydrocarbons through chemical reactions between microbial enzymes and the hydrocarbons. Nutrient requirements for these biodegradation reactions include nitrogen, phosphorous and

oxygen. These requirements were calculated based on the average composition of gasoline and fuel oil contaminants in the soil and the amount of soil to be treated, by solving the chemical reaction equations for biodegradation. The derivation of the reaction equations and calculation of the nutrient requirements are found in the appendices of the DSM design paper, "Generic Biocell and Biopile Designs for Small-Scale Petroleum-Contaminated Soil Projects.

Oxygen can be added to a biocell by tilling at least once per week, and to a pile through a system of slotted pipes to ensure even distribution of oxygen. Oxygen rates need to be greater than or equal to the calculated requirements. An excess oxygen supply is desirable to ensure adequate distribution of oxygen throughout a pile. Conversely, too much air can dry out the soil, decrease the biological activity, and volatilize the contaminants.

Based on the amount of oxygen required (found in the appendices of the DSM design paper), a 1- hp blower can be operated at a low flow rate while monitoring moisture content. If the soil is drying out, then the pump flow rate should be decreased or water should be added.

Nitrogen and phosphorous requirements can be satisfied by applying the appropriate fertilizer or a custom fertilizer blend based on the calculated requirements. Ammonia is the preferred source of nitrogen for hydrocarbons. Nitrogen and phosphorous can be added in the form of "off-the-shelf" fertilizer. If it is assumed that nitrogen and phosphorous initially in the soil is negligible, then a 6:1, nitrogen: phosphorous ratio is desirable. Therefore, a lawn fertilizer of 19:3:3 (nitrogen:phosphorous:potassium) ratio can be used.

The amount of fertilizer required has been tabulated in Table 1 based on the amount of soil to be treated and total petroleum hydrocarbons (TPH) found in the soil. All the fertilizer can be applied at the start of the project. The bacteria will consume the nutrients as they need them. Fertilizer can be added all at once, in dry pelletized form. Liquid fertilizer and periodic fertilizer application might also be viable options.

Table 1 lists the amount of fertilizer required to treat fuel oil or gasoline-contaminated soil for a range of contamination and quantities of soil to be treated.¹ The nitrogen:phosphorous ratio in the fertilizer should be 6:1, such as 19:3:3 (N:P:K) lawn feed which can be found in garden stores.

Monitoring Requirements

Regular sampling and analysis of contamination levels and microbial counts are necessary to monitor the progress of the biodegradation. Contaminant sampling and analysis should be conducted in accordance with the DEC Division of Spill Management's Sampling Guidelines and Protocols, and STARS Memo #1: Petroleum-Contaminated Soil Guidance Policy, under guidance of a DEC Regional Project Manager.

Microbe counts are conducted using Colony-Forming Units (CFU) analysis, a numerical tally of the total microbial population present, and Colony-Utilizing Population (CUP) analysis, the percentage of the microbe population capable of consuming the petroleum products. Low microbial counts and high contamination levels can indicate that the environmental conditions are not ideal for microbial growth. High microbial counts and lower contamination levels probably indicate that biodegradation is working well. Low microbial counts and low contamination levels can indicate that biodegradation was successful and that the microbes are dying off because the contamination (food source) is decreasing.

Table 2 is an example of an aggressive sampling and analysis procedure that may be used on a fast-track small-scale bioremediation project. Small-scale projects, including the sampling and analysis procedures, should be conducted under the guidance of a DEC Regional Project Manager. Each sampling plan can be developed on a site-by-site basis. Critical factors which indicate successful bioremediation include pH, contaminant concentration, and microbe count.

| Table 1: Amount of Fertilizer Required to Treat Fuel Oil or Gasoline-Contaminated Soil (lbs.) (N:P=6:1) | | | | | | | | | |
|--|--------------|---|-----------|-----------|-----------|-----------|-----------|-----------|------------|
| | | Volume of Soil (yd.³) | | | | | | | |
| | | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Total Petroleum Hydrocarbons (TPH) (ppm) | 1000 | 59 | 79 | 99 | 118 | 138 | 158 | 177 | 197 |
| | 2000 | 118 | 158 | 197 | 236 | 276 | 315 | 355 | 394 |
| | 3000 | 177 | 236 | 296 | 355 | 414 | 473 | 532 | 591 |
| | 4000 | 236 | 315 | 394 | 473 | 552 | 631 | 709 | 788 |
| | 5000 | 296 | 394 | 493 | 591 | 690 | 788 | 887 | 985 |
| | 6000 | 355 | 473 | 591 | 709 | 828 | 946 | 1064 | 1182 |
| | 7000 | 414 | 552 | 690 | 828 | 966 | 1104 | 1242 | 1379 |
| | 8000 | 473 | 631 | 788 | 946 | 1104 | 1261 | 1419 | 1577 |
| | 9000 | 532 | 709 | 887 | 1064 | 1242 | 1419 | 1596 | 1774 |
| | 10000 | 591 | 788 | 985 | 1182 | 1379 | 1577 | 1774 | 1971 |
| | 12500 | 739 | 985 | 1232 | 1478 | 1724 | 1971 | 2217 | 2463 |
| | 15000 | 887 | 1182 | 1478 | 1774 | 2069 | 2365 | 2660 | 2956 |
| | 17500 | 1035 | 1379 | 1724 | 2069 | 2414 | 2759 | 3104 | 3449 |
| | 20000 | 1182 | 1577 | 1971 | 2365 | 2759 | 3153 | 3547 | 3941 |

¹ Fertilizer requirements were calculated for the average composition of fuel oil and for gasoline. Amounts for gasoline and fuel oil were within 10% of each other; therefore, the same table will be used for both substances.

Table 2. Small-Scale Bioremediation Sampling Plan

Pretreatment Sampling: TPH¹, total soil concentration², microbes³, and soil sieve analysis (grain size distribution)⁴, and pH⁵

Sampling During Treatment:

every 4 - 6 weeks: TPH and microbes

every 8 - 12 weeks: TPH, indicator compounds⁶, microbes and pH

End of Season: TPH, total soil concentration, and microbes

Next Season Start-up: TPH, total soil concentration, microbes, and pH

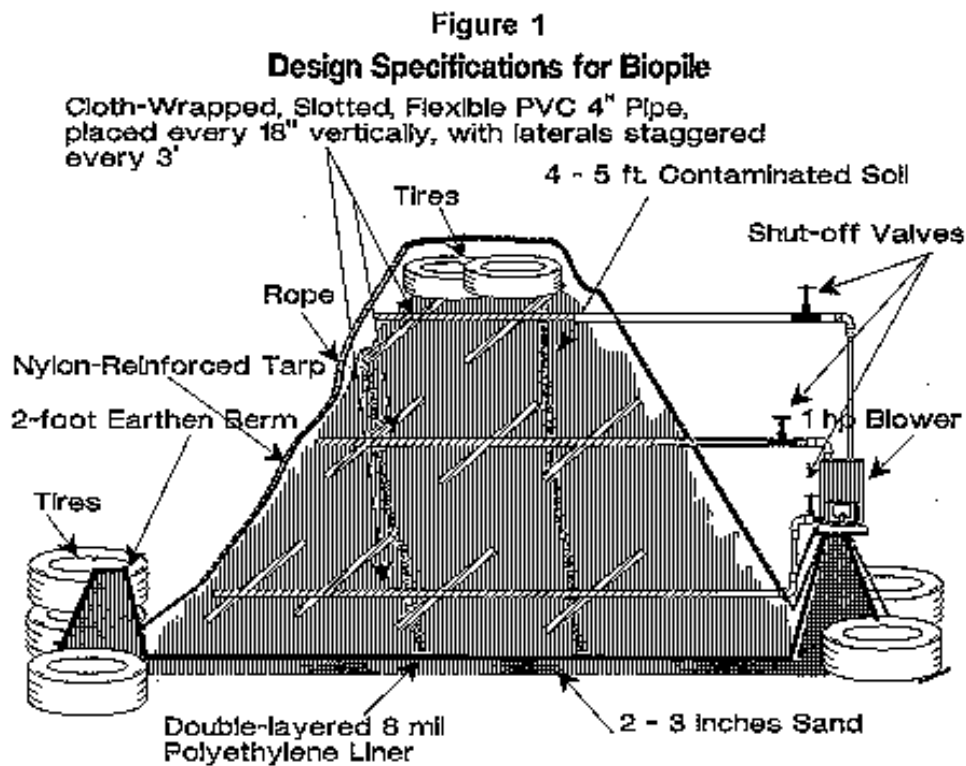
Project Closeout: Total soil concentration, TCLP², and microbes

- 1 TPH analysis is performed using EPA Method 418.1.
- 2 Total soil concentration analysis and TCLP extract analysis will be performed using EPA Method 8021 plus MTBE for gasoline and EPA Methods 8021 and 8270 (base neutrals) for fuel oil, in accordance with STARS Memo #1.
- 3 Microbe counts can be measured by colony-forming units (CFU) and colony-utilizing population (CUP). According to literature, 10^6 - 10^8 CFU/gram is the recommended level of microbes sufficient to support contaminant degradation.
- 4 Soil sieve analysis (grain size distribution) is conducted to classify soil type and to determine whether or not composting would be recommended to promote better aeration, such as in clays. Composting is beyond the scope of this guidance paper.
- 5 pH measurements can be done at a local garden store.
- 6 Indicator compounds to be analyzed for gasoline include BTEX using EPA Method 8020. Indicator compounds to be analyzed for fuel oil will be determined based on the total soil

BIOREMEDIATION APPROACHES

The engineering technologies for bioremediation can be characterized as physical controls, pump and treat, excavate and treat (ex-situ), and in-place (in-situ) technology. Physical controls consist of impermeable barriers designed to prevent contaminant migration and to allow natural biodegradation to occur. Pump and treat, and excavate and treat methods bring contaminated groundwater or soil to the surface where it is treated by biological reactors, possibly coupled with physical and chemical processes. In-situ technologies process the contaminated groundwater or soil in place in the subsurface. This paper addresses excavating and treating soil in a pile, also known as a biopile, or in a layer, also known as a biocell.

Biopile



Design Specifications and Operating Conditions for a Biopile

Setup

A biopile is set up according to the following design specifications and accompanying sketch. (See Figure 1.)

1. Clear and grade an area for construction. The foundation should be sloped to allow drainage and collection of rainwater.
2. Build a two-foot earthen berm around the pile to prevent run-on of surface waters and run-off of leachate. If this curb is constructed of soil, it should also be covered with the polyethylene liner to protect the curb from erosion.
3. Lay a double-layered 8 mil polyethylene liner on top of a 2 - 3 inch layer of sand and 2-foot berms. The liner should be durable enough so that soil-moving equipment will not tear it, and it is impermeable to leachate in the soil.
4. Pile the soil into a 4 - 5 foot flat-top pile on the liner, by adding soil in 1 to 2-foot lifts, installing air distribution piping and lime, fertilizer, and water with each lift.
5. While constructing the pile, install a ventilation system (a network of 4", slotted PVC piping woven throughout the pile, shut-off valves, explosion-proof blower, particle filter, moisture trap, and muffler) according to manufacturers' recommended practices. The piping system includes shut-off valves at each elevation of piping to allow varying air flow depending on moisture and contaminant levels. Slotted PVC pipes should be wrapped in a geotextile cloth to prevent soil from clogging the screens.
6. Add lime and fertilizer, and spray each soil layer with dechlorinated water until soil is wet but not puddly. (See the Operation section of this design for details on adding lime and fertilizer.)
7. Place tires or hay bales on top of the pile to provide air space between the soil and the cover, allowing air circulation under the cover.
8. Cover the pile with a black nylon-reinforced tarp, or at least a double layer of 8 mil polyethylene, or

a greenhouse-type structure, to protect the soil from rain and to keep it warm. This cover should be durable enough to withstand wind and weathering.

9. Anchor the cover using tires or hay bales around the perimeter of the cover, and ropes run over the top of the cover and tied to the tires or bales.
10. Secure the entire area with a safety fence to deter vandalism.

Operation

The process specifications include proper pH, temperature, moisture, nutrients and aeration:

pH

1. Determine the amount of soil to be treated.
2. Take one composite soil sample to a local garden store to be tested for pH. Refer to a liming chart for amount of lime (CaCO_3) to be added to obtain pH 7.
3. Add lime and mix with soil and fertilizer as the pile is constructed.
4. Check pH once per season.

Temperature

1. Operate at soil temperature above 40° F.
2. When soil temperature is below 40° F, follow end-of-season sampling procedures and secure site.

Moisture

1. Check soil weekly for dryness.
2. When the soil appears dry, remove cover, spray soil with potable, dechlorinated water until it is wet but not puddly. (Dehydration can be somewhat controlled by varying flow rate of vacuum pump. Water can be dechlorinated with tablets purchased at a local aquarium store.)
3. Adjust schedule or pump flow rate based on results.

Nutrients

1. Determine the amount of soil to be treated and the TPH of the soil. TPH analysis should be conducted using EPA Method 418.1, Modified Method 8015, or similar method. Refer to nutrient addition table in this guidance document.
2. Add fertilizer and mix with the soil and lime (if needed) as the pile is constructed.

Aeration

1. Supply air through a system of slotted pipes to ensure even distribution of oxygen. The design for the piping needs to be such that it avoids short-circuiting of air. Short-circuiting occurs due to varying resistance to air flow such as soil settling or clogging of pipe perforations. This results in air preferentially flowing through the path of least resistance. One way to avoid short-circuiting is to cover the perforated piping with a geotextile material to prevent clogging of the perforations. This geotextile material can be purchased in a plumbing or building supply store.

Notes: A manifold of piping with valves at the manifold may be a better design than a helical piping structure. It may improve air distribution by allowing control of the direction and flow rate of air passing through the piping. Air could be directed to the most contaminated parts of the pile to promote contaminant biodegradation. Air flows could also be directed to dry out the very wet areas or away from areas which may be drying out from too much air.

The smallest available diameter pipe is desired to allow maximum surface area of soil to be in

contact with the air.

Small diameter piping also facilitates easier sampling which may contribute to solving the aeration problem. Sampling challenges could be encountered when the piping is struck by the auger and subsequent auguring locations are necessary to avoid the piping obstruction. These sampling problems could also cause the geotextile material on the piping to be torn up. The purpose of this geotextile is to prevent soil from entering the perforations in the piping and contribute to poor air distribution in the pile.

An excess oxygen supply is desirable to ensure adequate distribution of oxygen throughout the pile. However, too much air can dry out the soil and volatilize the contaminants.

Based on the oxygen requirements found in the appendices of the original design paper, and the operating capabilities of a 1 hp pump, a 1 hp pump can be operated at a low flow rate to meet oxygen requirements. If the soil is drying out, then the pump flow rate should be decreased or water should be added.

Monitoring

1. Perform types, numbers, and frequency of sampling as outlined in the Monitoring Requirements section of this guidance document.

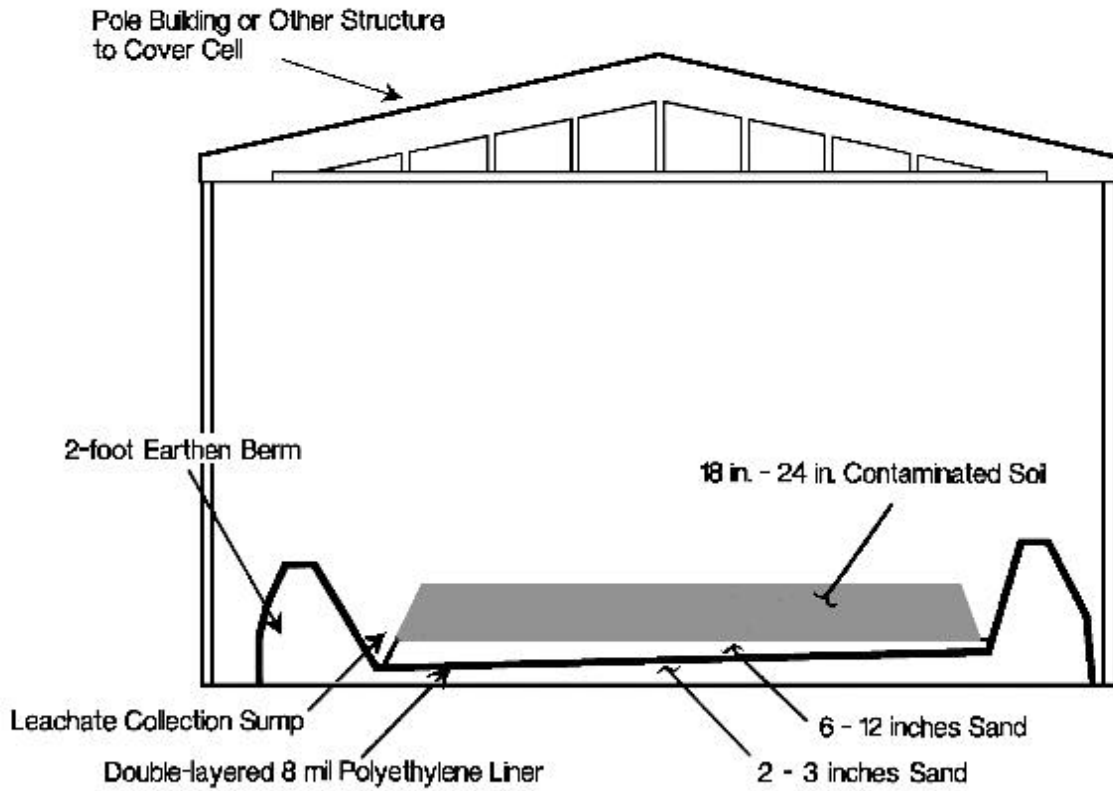
Project Close-out

1. Conduct process under the guidance of NYS DEC until the soil reaches the guidance values listed in STARS Memo #1 or until determined appropriate by NYS DEC. Perform closure samples as described in STARS #1.

Biocell

Figure 2

Design Specifications for Biocell



Design Specifications and Operating Conditions for a Biocell

Setup

A biocell is set up according to the following design specifications and accompanying sketch. (See Figure 2.)

1. Clear and grade a sloped area for construction. The foundation should be sloped towards a sump to collect leachate.
2. Lay a double-layered 8 mil polyethylene liner on top of a 2 - 3 inch layer of sand with 6 - 12-inch berms. The liner should be durable enough so that soil-moving equipment will not tear it, and it is impermeable to leachate in the soil.

Build a 6 - 12-inch earthen berm around the pile to prevent run-on of surface waters and run-off of leachate. If this curb is constructed of soil, it should also be covered with the polyethylene liner to protect the curb from erosion.

Cover the liner with a 2-foot layer of sand or gravel to protect against tilling equipment.

3. Spread the soil into a 18 - 24 inch layer on the sand.
4. While constructing the cell, add lime and fertilizer, and spray with dechlorinated water until soil is wet but not puddly. (See the Operation section of this design for details on adding lime and fertilizer.)
5. Cover the cell with a durable peaked or sloped-roof cover to prevent puddling on top of the cover and to protect against rainfall and the resulting leachate.

A peaked or sloped roof is required so that water will not collect on it. The cell cover also should be designed to allow soil tilling operations to occur without disturbing the cover, or to be easily removed and replaced to allow for soil tilling as needed.

Tents constructed of reinforced-nylon tarps can be used. However, this approach allows puddling of rain water on the covers and into the cells which makes it difficult to remove the cover for tilling.

Other alternatives which should be investigated are portable garages or surplus army tents or any

other viable structure. These structures should be cheaper than a pole barn, stronger than the tarpaulin tents, and tall enough that they will not have to be removed for tilling. An alternative is to leave the cell uncovered until rain becomes a problem, or the project could be active during the "dry" season only and shut-down when conditions are too wet and cold to support bioremediation.

6. Secure the entire area with a safety fence to deter vandalism.

Operation

The process specifications include proper pH, temperature, moisture, nutrients and aeration:

pH

1. Determine the amount of soil to be treated.
2. Take one composite soil sample to a local garden store to be tested for pH. Refer to a liming chart for amount of lime (CaCO_3) to be added to obtain pH 7.
3. Add lime and mix with soil and fertilizer as the soil layer is constructed.
4. Check pH once per season.

Temperature

1. Operate at soil temperature above 40° F.
2. When soil temperature is below 40° F, follow end-of-season sampling procedures and secure site.

Moisture

1. Check soil weekly for dryness.

2. When the soil appears dry, spray soil with potable, dechlorinated water until it is wet but not puddly.
(Water can be dechlorinated with tablets purchased at a local aquarium store.)
3. Distribute by tilling once per week.
4. Adjust schedule based on results.

Nutrients

1. Determine the amount of soil to be treated and the TPH of the soil. TPH analysis should be conducted using EPA Method 418.1, Modified Method 8015, or similar method. Refer to nutrient addition table in this guidance document.
2. Add fertilizer and mix with the soil and lime as the cell is constructed.

Aeration

1. Till at least once per week or supply air through a system of slotted pipes (see biopile design specifications).

Tilling is a very difficult, labor-intensive process in saturated soil, clayey soil, and soil deeper than 10 inches. Based on the difficulty of tilling the soil with a garden tiller, it is recommended that a farm tiller should be used, or that the cells should be constructed with thinner layers of soil. If thinner layers are used (10 inches or less of soil), a suitable rototiller could be rented at a garden store or a rental center, to efficiently turn the soil layer over in the cell.

An alternative for both the tilling problem in the cells and the aeration of clayey soils may be the use of oxygen-containing nutrient blends being marketed by various vendors in the industry. These blends, containing nutrients and oxygen in a solid form, are mixed into the soil and solubilize when moisture is added.

Monitoring

1. Perform types, numbers, and frequency of sampling as outlined in the Monitoring Requirements

section of this guidance document.

Project Close-out

1. Conduct process under the guidance of NYS DEC until the soil reaches the guidance values listed in STARS Memo #1 or until determined appropriate by NYS DEC. Perform closure samples as described in STARS #1.

COST ESTIMATES

Based on limited experience with this type of project in NYS, it is estimated that the cost of conducting this type of project can range from less than \$100 per ton to several hundred dollars per ton. Costs can vary greatly based on soil quantity, soil type, amount and type of contamination, access to and choice of materials and labor, and the monitoring plan.

ACKNOWLEDGEMENTS

This Document, prepared by the NYSDEC DSM, presents guidelines and recommended practices for bioremediation of small-scale amounts of petroleum-contaminated soil.

The information contained herein is based on reference documents and a research project completed with the dedicated and cooperative effort of Stewart's Ice Cream Shops, Inc., Lebanon Valley Landscaping, Inc., American Spill Abatement, Inc., and Waste Stream Technology, the USEPA and the NYSDEC.

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