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OIL & GAS WELLSITE RECLAMATION CRITERIA IN ALBERTA
Bioremediation of Invert Drilling Waste

Ranju Shergill, B.Sc., B.I.T.

Alpine Environmental Ltd.
101-3740D 11A Street N.E.
Calgary, Alberta, T2E 6M6

ABSTRACT

The fundamental principle of wellsite reclamation criteria is that reclaimed site conditions are to be assessed by comparing them to documented pre-disturbance conditions, or adjacent lands. The differences must not interfere with normal land use and must support comparable self-sustainable growth.

Proper waste management and disposal methods which permit drilling operations to take place with temporary effects on the land, while also reducing the cost and time required to obtain final reclamation, are integral steps in successful site reclamation. The goal of all disposal options is to protect the environment and return the disposal site and any affected areas to equivalent land capability.

Landfarming is a drilling waste disposal option for heavy invert mud system. By applying the drilling wastes over a selected plot of land and keeping the waste application within loading limits set by ERCB, landfarming is a productive efficient method of reclaiming contaminated sites.

Landfarming may take place in either the topsoil or the subsoil, although the topsoil has been shown to provide a more favorable environment for microbial biodegradation of hydrocarbons in invert drilling muds. Due to the soil texture, nutrient availability and increased aeration, landfarming in the topsoil may lead to a more efficient and faster degradation rate of the drilling waste.

INTRODUCTION

The construction of wellsites and leases in the oil and gas industry results in a disturbance to the land in terms of land use, vegetation damage, soil compaction and landscape damage. These disturbances must be dealt with when following procedures in reclaiming the site. The damage or disturbance to the original condition of the site is addressed in the criteria used to assess reclamation procedures and results. Drilling waste disposal sites are usually one of the most difficult sites to reclaim in the oil and gas industry, due to contamination of the site with heavy oils and salts.

LEGISLATIVE REQUIREMENTS FOR RECLAMATION IN ALBERTA

The Alberta Environmental Protection and Enhancement Act requires the reclamation of land and obtaining a reclamation certificate. This Conservation and Reclamation Code of Practice for Alberta is enforced by the Alberta Environmental Protection and promotes and encourages the following:

1. The return of a disturbed site to a land capability equivalent to the pre-disturbance land capability which is sustainable under normal management of the land.
2. The soil, landscape and vegetation conditions of pre-disturbed land are set as the comparable standards for achieving reclamation.
3. Pre-construction site assessments are used to address and identify any potential soil, landscape and vegetation impacts.
4. The conditions of the soil, landscape, and vegetation are to be conserved in order to achieve a minimal impact on the site with construction, thus reducing the remedial requirements.
5. The soil conditions and the sensitivity of the soil to disturbance must be addressed prior to construction.
6. An attempt must be made to protect the native vegetation on the project site and any reclamation must attempt to achieve rapid re-establishment of vegetation that is compatible with the adjacent land.
7. All activities involved with the project site must be monitored and recorded.
8. On-site supervision of reclamation activities should be conducted by personnel responsible for environmental quality control.
9. Reclamation practices must be carried out on as much of the disturbed area as possible.
10. Site assessments must be conducted to monitor the effects of reclamation practices prior to obtaining a reclamation certificate.

The fundamental principle behind the Conservation and Reclamation Code is that the reclaimed land conditions are assessed by comparing the reclaimed conditions of the soil, landscape, and vegetation to those of adjacent lands. The differences observed between reclaimed land and adjacent lands must not interfere with normal land use (P.I.T.S., 1994). The reclamation criteria for wellsites and associated facilities are applicable to oil and gas wellsites, leases, access roads, and off-site borrow pits, sumps, oil production sites, and campsites. On wellsites, proper waste management and disposal methods will allow the drilling operation to take place with a temporary effect on the land, while also reducing the cost and time required to obtain final reclamation. The goal of all disposal options is to protect the environment and return the disposal site and any affected areas to equivalent land capability.

RECLAMATION REQUIREMENTS

Reclamation procedures involve clean-up of the contamination onsite in order to meet Alberta Environmental Protection requirements, recontouring of the site to original grade, controlling any erosion problems, replacing soils in the same sequence of soil profiles as found prior to construction, correcting soil compaction, and revegetating the site with the native species or an approved species of vegetation which is compatible with the intended land use.

Field assessments have primarily been used to determine reclamation success, and the criteria used in reclamation address specific parameters used to compare soil, landscape, and vegetation of the project site with pre-disturbance conditions. These field assessments are then used to apply to the Canadian Land Reclamation Association through an application. This application includes a brief summary on the site history, spill or contaminant information, the use of herbicides, sterilants, fertilizers and soil amendments, and the presence of underground facilities.

RECLAMATION CRITERIA

The criteria used to assess reclamation identify three construction time periods, pre-1983; when there was no legislated requirement for soil salvage, 1983 to 1994; when soil salvage and replacement were required, and 1994 and later; when these criteria are in effect. The criteria for reclamation are also based on land use which is categorized into cultivated, grassland, forest and peat.

Cultivated land includes all lands that have been ploughed to prepare a seed bed at some point in time. The criteria for this land use apply to lands under continuous and rotational cropping systems and hayland. Grassland includes all lands that are permanently grassed including grazing dispositions on public lands, native prairie and grassland areas. Forested areas may have potential for multiple use including cultivation and the criteria for peat lands apply only to those lands which have not been cultivated.

SITE BIOREMEDIATION

The steps involved in bioremediation of a contaminated site must take all the above considerations for reclamation into effect. The criteria for reclamation are important considerations in the process for efficient, cost-effective, and successful bioremediation. The first step in bioremediation involves a site characterization in which the contaminated site is assessed in terms of the nature of the material to be biotreated and the extent of the problem. The amount of material to be treated is estimated and the physical characteristics of the site are evaluated such as; soil type, depth of groundwater, direction of groundwater flow, and plant, animal, and human life forms which may act as receptors for the contaminant.

A risk assessment is then used to measure the potential for the contamination to escape from the source and interact with any receptors in the environment. This may be a qualitative assessment which describes the routes of transport, and effects on receptors. A quantitative assessment gives the degree of adverse effects on any receptors in the environment.

Sampling of the site is then performed to determine the quantity of contamination and the extent of contamination. Background levels are also checked to determine the extent of contamination. This analysis may be carried out on soil, air, and water samples.

Contamination migration is detected due to the danger of contamination in the food chain from water courses. Groundwater is a source of potable water and groundwater monitoring wells may be used to determine if the contaminant has reached the groundwater (Francis, 1991).

After characterizing and assessing the contamination site, remedial measures are then taken to reclaim the site to reclamation criteria specifications. One of the more important physical parameters required in the planning phase of reclamation is the nature and type of the soil or soils in which the contamination is located. An open porous soil will offer more options for remediation, whereas a tight compact soil will limit the available options. On the other hand, a very porous, sandy soil may also require a much more aggressive remedial action such as immediate excavation of the contaminated soil because the contamination will migrate more rapidly. Bioremediation is known to work best in warm, loose, moist porous soils characterized in topsoils (Cole, 1994).

LANDFARMING

The application of hydrocarbons to soil has been carried out as a drilling waste disposal method for invert muds, which may be heavy diesel-based oily muds. This disposal method know as landfarming, involves hydrocarbon contaminated soils being excavated and transported to a landfarm site for treatment. The oily waste or contaminated soil is ploughed into the soil at the landfarm and treated with amendments to aid hydrocarbon degrading microbes in the soil to degrade the organics of the waste i.e. the hydrocarbons. The treatability of invert drilling mud wastes on soils in Alberta is a growing environmental concern. Landfarming is a feasible method of disposal for these wastes which allows for soil microbial activity to decompose the harmful and undesirable components of the waste.

Landfarming involves spreading excavated soils over a large area to encourage natural remediation and is an efficient form of bioremediation since it allows for control of nutrients, moisture and temperature parameters. The major equipment that may be used for this process are earth moving equipment, tractors, disks, rototillers, mixing tanks and sprinklers to provide nutrients to the soil, diversion ditches, and dams or ground covers to control run-off.

The process of landfarming drilling waste requires submission of a waste management and disposal plan to the appropriate regulatory authority for approval prior to spudding the well. There are currently very few ERCB regulations for the landfarming process and the program is carried out through monitoring of the soil and experimenting with "doses" of amendments for particular types of drilling waste to be landfarmed.

Amendments such as mulched straw, fertilizers, calcium nitrate and calcium sulphate are incorporated into the waste/soil mix in the landfarming process. Invert cuttings in the 7% - 10% hydrocarbon range with low salinity values can be successfully landfarmed in 12 to 18 months with a fully reclaimed site in approximately 2 years of initiating landfarming.

Final reclamation of the site can take place once the oil content of the landfarm site reaches 0.5% in the topsoil or 0.1% in the subsoil. At this point, vegetation can be re-established and the site needs to be monitored only for nitrogen levels. The residual hydrocarbon will continue to be biodegraded by microbes which use up nitrogen perhaps to the point of stunting plant growth. A light application of nitrogen for an additional growing season should alleviate this problem.

HYDROCARBON BIODEGRADATION

In the soil profile, hydrocarbons move downward by force of gravity, although some horizontal spreading will also occur because of capillary forces between the migrating liquid and soil particles. Petroleum products heavier than diesel such as invert drilling muds, have very low flow rates due to their high viscosity and releases into heavy dense clays will not migrate rapidly (Cole, 1994). Surface volatilization of hydrocarbons may be quite rapid within the first few days of application (Odu, 1977). This may be attributable to a large initial decrease in the oil content of the landfarm soil.

Biodegradation, bioremediation, and landfarming are all related, they are just different approaches to the same technology: "Letting nature takes its course". Because petroleum hydrocarbons are similar to biological molecules and plant residues, they can be metabolized by native soil bacteria. The lighter hydrocarbons are more easily degraded by indigenous bacteria. The principal soil bacteria involved in hydrocarbon biodegradation are; *Pseudomonas aervginosa,* (which is the predominant group of bacteria), *Achromobacter,* and *Alcaligenes radiobacter* (Gossen, 1973).

Bioremediation is a process of aerobic microbial oxidation (oxidative degradation) of hydrocarbon contaminants to carbon dioxide and water using naturally occurring soil bacteria. The overall process may be "enhanced" or accelerated by providing nutrients to the bacteria, or by providing laboratory cultured bacteria, or both. The rate of conversion of hydrocarbons to carbon dioxide and water is strongly dependent on the following factors; soil porosity, oxygen content in the pore (interstitial spaces of the soil), moisture content in the interstitial spaces of the soil, macronutrient content (phosphorus and nitrogen), soil temperature, and soil pH. The chemical reaction describing the biodegradation of hydrocarbons in soil is as follows (Cole, 1994):

contaminant nutrients oxygen

$$(HC)_X + (N, P, S) + O_2 \longrightarrow \text{Acid Intermediates} \longrightarrow CO_2 + H_2O + NO_3^{-} + SO_4^{-2} + \text{Energy} + \text{Bacterial Cells}$$

Up to 60% of hydrocarbons are used by bacteria in the soil for reproduction and cell materials. The availability of nutrients such as nitrogen and phosphorus controls the growth of the soil microorganisms and consequently the rate of hydrocarbon degradation. Nitrogen is the most important nutrient required for biodegradation due to soil microorganisms which consume large quantities of added nitrogen in using the hydrocarbon as a carbon source for their own growth (Toogood, 1977). Free access of oxygen must also be available for the aerobic process in landfarrning and emphasis is often placed on soil cultivation and aeration in order to ensure aerobic conditions for degradation.

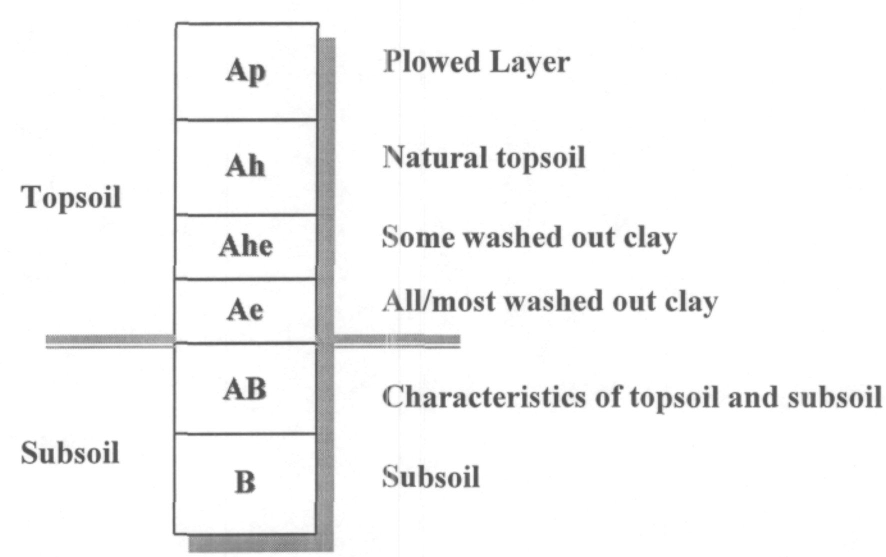
LANDFARMING IN THE TOPSOIL VS. THE SUBSOIL

An important criteria in determining the success of a reclaimed site is assessing the quantity of topsoil remaining after all reclamation procedures have been performed. In assessing reclamation, the total depth of the topsoil on the reclaimed site is measured against the total depth of topsoil on surrounding sites, or from documented pre-construction site data. Obtaining a "pass" for reclamation requires the presence of a certain portion of topsoil remaining on the project site after reclamation. Therefore, in landfarrning practices, CLRA (Canadian Land Reclamation Association), recommends to use "two-lift stripping" when preparing or constructing a site. This means the upper soil profiles are lifted and stored separately to conserve the integrity and quantity of topsoil. It is then suggested to landfarm the oily wastes in the remaining subsoil on the landfarm site. The use of two-lift stripping is believed to increase the chances of the organic matter being retained in the rootzone.

For private land and cultivated public land, topsoil is defined as all the A horizon (Ah, Ahe, Ae, and Ap) material within the soil profile (figure 1). The characteristics of topsoil include a higher organic matter than in subsoils, a darker colour than subsoils, and a granular structure. Topsoil includes the major zone of root development for plants and it contains the nutrients and water necessary for plant growth. The subsoil refers to the B and C horizons and lays immediately beneath the topsoil. Subsoil is generally lighter in colour than topsoil and is more structured. Soil compaction is another parameter in achieving reclamation success because it may result in a decreased ability of the root to penetrate into the subsoil.

In theory, topsoil is much more aerated than subsoil due to the texture. The subsoil often consists mainly of fine clays which are not as aerated as in the topsoil which also contains a higher content of organic

FIGURE 1: Horizons of Topsoil in Soil Profile



matter and nutrients. In laboratory studies, the number of soil micro-organisms can be evaluated using the agar plate count technique. In comparing the number of micro-organisms between topsoil and subsoil, there is a significantly higher portion of microbial activity in the topsoil (Ashworth, 1995). Background levels of microbial activity are seen in subsoil samples which indicates the topsoil would provide a more appropriate environment for hydrocarbon degradation. This is opposed to the recommended practice of landfarming in the subsoil as per the CLRA. Experimental approaches have proven oil degradation to be more rapid in a well-cultivated fertile soil such as topsoil, than in a soil low in organic matter such as in the subsoil (Toogood, 1977). Successful reclamation of a hydrocarbon contaminated site depends upon the development of an active soil microbial community.

Topsoil has been shown to aid hydrocarbon degradation also when it is added as an amendment to a landfarm site for reclamation purposes. Due to the high carbon exchange capability in topsoil, nutrients are immobilized thus reducing fertilizer loss by leaching. This results in a decreased application of fertilizer and other nutrients, thereby making landfarming more cost-effective when it takes place in the topsoil. The high moisture holding capability of topsoil also reduces potential moisture stress and provides the moisture necessary for efficient microbial activity.

COSTS OF LANDFARMING

The costs of landfarming may be spread over the long-term and may include the costs of amendments, rotovating the soil, monitoring the site, and the soil analyses required to update the landfarm program. Landfarming is a traditional and cost-effective method of reclaiming hydrocarbon contaminated sites. This disposal method has been highly successful and cost-effective in disposing of oily drilling wastes. The benefits to landfarming in order to achieve reclamation is that it is relatively inexpensive, low-tech, non-labor intensive, and results in clean soils after relatively short periods of time. Landfarming practices, when carried out properly, lead to successful reclamation of sites used for drilling waste disposal.

CONCLUSION

Landfarming invert drilling muds can lead to successful, cost-effective reclamation when carried out appropriately. Through ongoing monitoring of the site and the proper application of amendments to ensure continuous biodegradation of the oil content in the drilling waste, the soil can be "cleaned" or returned to original conditions in a relatively short period of time. Bioremediation of contaminated sites by landfarming involves using naturally occurring soil processes to return disturbed soil to original conditions.

The criteria in reclamation certification must be considered at all times during landfarming or other reclamation procedures. Recontouring of the landscape, revegetation of the site and ensuring a comparable soil profile with original conditions are some of the steps required in obtaining reclamation in terms of the Conservation and Reclamation Code in Alberta.

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