

From Grey to Green: Transforming Oily Drilling Waste into a Soil Amendment

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Abstract

Operators drilling their deep prospects in the foothills of Western Canada with oil-based mud systems continually face the question, "How is it possible to effectively dispose of oily drilling waste in a manner that does not harm the environment or create future liabilities?"

To meet this challenge, Unique Oilfield Technology Services (UNOTEC) began the development of a 2-step bio-remediation process capable of naturally immobilizing and detoxifying hydrocarbons. By 2001, this process had been used on well over 100 locations drilling sites in Alberta and BC and received patent protection in the US as well as pending status in Canada. Today, both domestic and international interest begins to grow.

The first step in the process is bio-treatment. Drilling waste is blended with organic amendments specifically chosen for their ability to function as natural anti-leaching mechanisms, sources of hydrocarbon-degrading organisms and nutrients (primarily complex nitrogen), as well as moisture control and structure building agents. Unlike biopiling or land farming, waste and amendments are blended in a controlled fashion according to pre-determined mix ratios. A calibrated, mobile mixing unit is used to accurately weigh and evenly blend waste with amendments to prevent hotspots. The homogeneous endproduct is compost-like in texture and suitable for spreading on self-draining locations. In some cases, bio-treatment mixtures with oil contents greater than 20% have been safely spread over drilling sites.

The second step involves bioremediation or microbial detoxification. The bio-treatment mixture is spread as thinly as possible over the drilling site to maintain passive aeration and stimulate enhanced degradation of hydrocarbons by microorganisms. Depending on the thickness of the spread, periodic tilling with light equipment (ie. quads) may be required to maintain aeration, moisture and prevent "crusting". Unlike land farming, bio-treatment or waste mixture is not blended with soil. Receiving soil is used only as a platform. Mixture and soil samples are collected separately to track degradation rates and detect any movement or leaching of hydrocarbons into receiving soil.

The focus of this paper is to examine the ability of the bio-treatment to render oily drilling waste suitable for land spreading, microbial detoxification and transformation into a soil amendment. Technical data from actual field projects and 30 field plots established by the University of Alberta at their Ellerslie Field Research Facility as part of a 5-year research collaboration, will be presented. Also, a case study will explain how the remediation process was used in conjunction with the first salt-free oil-based drilling

fluid and specialized solids handling, to achieve pre-reclamation certificate waste closure recognition of the site.

Introduction

Prior to the introduction of low and no salt (non-invert) oil-based muds (OBM), operators drilling their deep basin prospects in the foothills of Western Canada continually faced the challenge, "How is it possible to cost effectively dispose of oily drilling waste on site in a manner that does not harm the environment or create future liabilities?"

At the time, no effective *in situ* solutions were available. Invert drilling waste, heavy in salt and oil, was bulked and hauled long distances to landfills for disposal. In many cases, materials were hauled from locations with limited access under poor weather and road conditions further increasing the risk of accidents and spills.

Three important developments began forcing operators to explore on-site waste disposal options. Firstly, the costs, risks and liabilities associated with transporting and storing potentially hazardous waste were being measured under stricter corporate policies and environmental regulations. Secondly, the development of the CANOIL process (US Patent 6,074,563 & 6,251,288, CAN Patent 2,175,859) was allowing OBM systems to be run with clear fluid (i.e. no internal water phase) and generate drilling waste with little to no salt. Lastly, improvements in solids control and fluid recycling technology was reducing the overall waste volume as well as their respective oil contents. The cumulative effect of these developments lead Unique Oilfield Technology Services (UNOTEC) to develop a two step bio-transformation process used to treat, spread and detoxify oily drilling waste so that it could safely disposed of on the drilling location.

Bio-Transformation: Making things change for the better

The fundamental premise behind bio-transformation is microbial waste detoxification; using indigenous microorganisms to degrade petroleum hydrocarbons to the point where they cease to have a negative effect on plants and soil organisms. Changing the nature of waste not only eliminates risk and liability, it brings new value to formally useless material. In other words, waste ceases to be waste. The UNOTEC approach to bio-transformation consists of two distinct steps: bio-treatment and detoxification.

Bio-Treatment: Creating the ideal environment

It is no secret that hydrocarbons are considered to be susceptible to biodegradation under "ideal conditions". Enhanced biodegradation of hydrocarbons is possible only if the following components are readily available: hydrocarbon degrading microorganisms, nutrients (primarily nitrogen), water, and oxygen. As such, the objective of the bio-treatment (US Pat 6,187,581 B1, Can Pat 2,257,706), blending oily waste with selected organic amendments, is not only to create this ideal micro-environment by providing all the necessary components but also to ensure hydrocarbons remain in place and in a non-leaching state until they are reduced to non-toxic levels.

The key ingredient to bio-treatment is oilseed meal. These meals play important roles as oil absorbent/adsorbents or anti-leaching agents and source of hydrocarbon degrading microorganisms and complex nitrogen. These meals' oleophilic (oil-liking) qualities are largely attributable to its former origins as an oil seed. As a by-product of the oil extraction process, Canola meal has the ability to “absorb” or “take in” as well as “adsorb” or “hold onto” a wide range of hydrocarbons even in the presence of water.

Canola: More than just a meal

In Canada, Canola (*Brassica napus*) meal is used to immobilize oil and prevent leaching following land treatment. Its ability to act as an effective organic absorbent was first established in the UK where it has been successfully marketed as desirable pet litter with “high absorptive capacity, odor prevention and resistance to animal tracking or sticking to paws”. Affinity or molecular attraction tests on oil have indicated that the meal is capable of adsorbing as much as 70% of its weight in hydrocarbons (from the diesel range) in the presence of water. For this reason, Canola meal is valued as an important anti-leaching ingredient for bio-treatment.

Canola meal plays an equally important role as a source of complex nitrogen. In a complex or non-elemental form such as protein, the nitrogen is not readily soluble and therefore, stays in the bio-treatment mixture where it will be used. As such, it is used to balance the amount of carbon contributed by hydrocarbons to maintain a metabolism supporting carbon/nitrogen ratio.

Primarily composed of protein, Canola meal is a rich source of complex nitrogen. As a result, the meal is valued as a feed supplement for cattle and poultry. CanAmera Foods reports that Canola meal consistently contains 36% protein and 5% complex nitrogen by total weight. As nitrogen is considered as an essential “growth stimulating agent” for microorganisms, Canola meal also plays an important role as a catalyst for microbial activity. Unlike salt-based fertilizers, complex nitrogen is much more resistant to leaching and is released slowly over time, making it an ideal for bio-treatment.

Wood: No better bulking

Availability of oxygen controls the level of efficient microbial metabolism. To maintain a continuous air supply by passive air induction, wood bulking are added to the bio-treatment mixtures. In addition to building and maintaining long term structure within bio-treatment mixes, the “hydrophilic” or “water-liking” nature of the woody material will aid in maintaining essential moisture within the mixture and prevent the mixture from becoming hydrophobic. Also, decomposing wood fiber produces valuable plant material.

Another added value of using Canola meal and wood bulking is their ability to be sources of indigenous microorganisms. Due to their organic nature, these amendments are important sources of “workers” (bacteria and fungi) capable of detoxification by utilizing hydrocarbons or changing their nature.

Mixing: It's all about making contact

Equally as important as the amendments to the bio-treatment process is the mixing technology used to evenly distribute them into a homogeneous mixture free of "hot" as well as "cold" spots. Using a highly calibrated mobile mixer equipped with four offset augers, load cells and weight scale (a design adapted from the agricultural industry,) drill cuttings are blended at specified weight ratios according to a pre-determined mix prescription that balances carbon and nitrogen levels. This assembly-line approach to waste treatment is highly auditable as the weight of all waste and amendments are recorded on mixing logs.

The end product is a homogeneous mixture that is suitable for land application on site in accordance with regulatory guidelines. The mixture is very similar in texture and appearance to horticultural compost. By incinerating samples of bio-treatment mixture and analyzing the ashes, the University of Alberta has reported that there is a maximum of 2% variability in weight among bio-treatment mixes.

Although the treatment process increases the original volume of residuals by two to three times, the focus of the process is to treat oily residuals not dilute them. In fact, the difference in the percent total extractable hydrocarbons between untreated residuals and bio-treatment mixtures is typically in the range of only 2 to 3%. For example, if the total extractable hydrocarbon content for a 100 cubic metre volume of residuals is 12%, the resulting post treatment volume will be approximately 300 cubic metres and have an oil content equal to 9 to 10% by weight. This phenomenon is attributable to the relatively “light and bulky” or low bulk density (weight per unit volume) of Canola meal and wood bulking.

The mixing or treatment step also provides an opportunity to collect a truly representative sample used to characterize the entire mixture. A sub-sample, of equal volume, from each mix load is collected to produce a true composite. All sub-samples are blended together in an additional mixing step, from which a sample is collected for laboratory analyses. The initial characterization of bio-treatment mixtures uses a standard set of laboratory analyses, collectively referred to as the UNOTEC Suitability Test. These analyses include leachability, salinity, C:N balance, and total extractable hydrocarbons.

The mixing operation is completely mobile requiring minimal set-up time. As a result, the mixing treatment process has received notoriety for the amount of material that treated in a single 10-hr day (~500 Tonnes) and the amount that traffic is reduced in wildlife sensitive areas when compared to landfill hauling.

Detoxification: Cleansing is the key

The most cost-effective way to maintain aeration in bio-treatment mixtures is to be spread it over land. This maximizes the amount of surface area available for passive air induction into the spread material and minimizes the need for frequent tilling. Field research reports from 30 field plots established by the University of Alberta suggests, "the thinner, the better". The thickness of the spread determines the amount the post-spreading tillage required to maintain structure and aeration in spread material. Field observations indicate that mixtures spread at 10 centimetres or less require little to no annual tilling.

Land application is not to be confused with landfarming even though both share the same "Land Treatment" classification in the existing Alberta Energy & Utilities Board (AEUB) Guide-50 Drilling Waste Management Guidelines. In landfarming, drilling waste is applied directly to soil and blended using agricultural tillage equipment. Subsequent tilling is necessary to maintain aeration and blend in additional fertilizer. The frequency of additional tilling and fertilizing depends on the amount of clay in the soil.

UNOTEC's approach to detoxification on is much less labor intensive. In the land application process, bio-treatment mixtures are spread evenly over topsoil or subsoil, regardless of clay content, using a spreader unit equipped with low pressure tires. Once spread, the mixtures require no additional admixing, tillage or fertilizer to deplete hydrocarbons to residuals levels. Receiving soil is used only as a platform. Admixing is not permitted until a test mix (reclamation simulation) proves that the incorporation of mix into soil will meet Tier 1 closure criteria.

To prevent "bath-tubbing" and promote enhanced biodegradation, spread areas are constructed to be self-draining. Diversion berms are used to prevent water from running on to spread areas and disperse run-off. The leachability of mixtures is measured prior to spreading using a standard procedure called TCLP (Toxicity Characteristic Leaching Procedure). It was adopted as a standard means of characterizing the oil immobilization capacity of Canola meal and wood shavings in bio-treatment mixes before any material is spread over receiving. It is an aggressive procedure that involves a 20:1 dilution and 18-Hr agitation of samples to produce a leachate. The procedure is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid and multiphase wastes. The objective is to use the procedure to generate worst case scenario leachate that can undergo laboratory testing. Oil analyses performed on TCLP leachates consistently range from 5-20 milligrams per litre, well below the 100ppm pump-off limit for sump fluids imposed by Guide 50. These oil contents have been found to be higher than those in actual leachate and run-off samples collected from the field.

Biodegradation: How long does it take?

Laboratory and field reports show evidence that the reduction of hydrocarbons in bio-treatment mixtures is attributable to bioremediation, or to the “work” of indigenous microorganisms, rather than volatilization and weathering. In the spring of 1998, the University of Alberta was invited to participate in the long-term research aimed at evaluating the efficacy of bio-treatment mixtures to immobilize and microbially decompose oily drilling residuals.

On June 4, 1998, under the direction of Dr. William McGill, Professor of Soil Biochemistry, 30 field plots were established at the Ellerslie Field Research Facility. The objective of the long-term research is to collect bioremediation data. The most important question is how quickly are hydrocarbons degraded. By averaging the degradation rates of the 30 plots, the University has concluded that hydrocarbons are degraded at a rate of 30-35 tonnes per hectare per year in a single bioremediation year that ranges from 142-188 days in Alberta. Similar rates have been reported from field observations on over 100 sites currently being monitored. Also, additional reporting has confirmed that hydrocarbons are degrading at a faster rate than the Canola meal and wood shavings.

The earliest point in time when bio-treatment mixtures cease to be limiting factors to the reclamation of the sites on which they are spread is determined by "test mixing". This program was designed to simulate reclamation by blending mixtures with 15 centimetres of receiving soil that represents the recommended maximum incorporation depth permitted under G-58 guidelines. Test mixing has confirmed that the time to closure is largely a function of the initial oil content and overall volume/thickness of spread material. Average waste volumes of 100-200 cubic metres of raw waste are reaching hydrocarbon closure (as per new CCME fractions) in two to three years.

Often proof that bio-treatment mixtures are detoxified is evident in the form of grass that has naturally established well before closure criteria are met. In one particular case, 60+% coverage was achieved in the summer after a spread area with an average oil content of 2% was accidentally seeded.

Case Study: Husky Cordel 6-11-43-16W5 Background

In October of 1998, 90 cubic metres of salt-free drill cuttings (shaker screenings and centrifuge underflow) were bio-treated on a high alpine lease for Husky Oil north of Nordegg. This area is subject to high rainfall and relatively mild summer temperatures. The volume grew to 330 cubic metres after mixing, with an oil content of approximately 20%. The final bio-treatment mixture had an oil content of 12.2% by dry weight. This relatively low oil content was largely due to the high volume of fluid that was recovered from cuttings via drainage tanks (supplied by UNOTEC) and centrifuges. The material was spread on 0.3 hectares of the 1.0 hectare lease in December of that year at an average thickness of eight centimeters. The mixture and receiving soils were sampled yearly and tilled only 3 times.

In the fall of 2001, a test mix was conducted that showed that the spread area was capable of meeting closure even though the well itself remained suspended. Annual monitoring found no increases in the hydrocarbon levels for underlying receiving soils. In April of 2002, a memorandum of understanding was received from Alberta Sustainable Resources Development-Nordegg recognizing that "based on the data presented, it is recognized that the bio-treatment has degraded to the point where it ceases to be a limiting factor to the reclamation of lease".

Note: Technical summary of project will be presented at symposium.

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