

# **BIOREMEDIATION OF DRILL CUTTINGS IN AN ARID CLIMATE**

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## **ABSTRACT**

Discharge of oil based drill cuttings is prohibited offshore in Egypt. This project involving evaluation of bioremediation of drill cuttings containing 18-25% petroleum hydrocarbons necessitated different approaches due to the arid Egyptian climate. Four bioremediation methods using mainly locally available materials were evaluated: Straw and Chicken Manure; Straw and Fertilizer; Polyethylene Cover and Fertilizer; Polyethylene Cover and Chicken Manure.

Methods using fertilizer did not show any appreciable evidence of hydrocarbon biodegradation. However, accelerated hydrocarbon degradation was observed with the methods using manure; within six months, concentrations of hydrocarbons were reduced to 3.3% total petroleum hydrocarbons. Concentrations of hydrocarbons present after two years represented less than 1% total petroleum hydrocarbons.

Changes in the ratio of light to heavy extractable hydrocarbons were also examined. Parameters monitored during the project include: LEPH (light extractable hydrocarbons, C10-C19), HEPH (heavy extractable hydrocarbons, C19-C32), phosphates, nitrates, Standard Plate Count, pH, moisture and polyaromatic hydrocarbons. The study concluded in June 2003. The results promote adopting bioremediation as an industry practice in Egypt using locally sourced materials.

## **INTRODUCTION**

The discharge of oil based muds (OBM) and drill cuttings from offshore drilling activities is prohibited in Egyptian waters. As a consequence, these materials are currently transported onshore to the East Zeit Base and disposed of by burying in unlined pits. This practice is not considered to be a viable long term or sustainable solution as there is a risk for contamination of groundwater and the adjacent subsurface material. To address this situation Devon initiated a program to study the potential for bioremediation to treat OBM and drill cuttings obtained from current and previous offshore drilling activities the East Zeit Concession located in the Gulf of Suez. The OBM and drill cuttings contained approximately 18 to 25% w/w petroleum hydrocarbons (predominately diesel). In order to determine the best method of remediating the oil based cuttings a program consisting of four different types of treatments were developed. The aim of this program was to study the effects of different nutrients and composting materials to enhance the natural biodegradation of the OBM and drill cuttings.

## **PROJECT INITIATION**

The first stage of the project involved identifying the limitations of the local environment and developing an acceptable site to accommodate the volume of OBM and drill cuttings provided for treatment followed by inventorying available equipment and materials.

The local environment where the East Zeit shorebase is located is best described as a desert, characterized by wide daily and seasonal temperature variations, very limited moisture available and the occurrence of hot dry winds. Surface material is composed of very coarse to coarse sand, abundant pebbles and many small and medium sized rocks. The principal limitations for performing bioremediation in this environment were identified to be high evaporation rates, high porosity and the high surface temperatures. The presence of microorganisms necessary to remediate may also be lacking or limited.

The selection of the bioremediation pilot project site was based on meeting the following criteria: no interference with existing operations; no nuisance or potential health risk to the camp (odors) and was of sufficient size to accommodate the volume of current and future OBM and drill cuttings. A site was selected on the East Zeit concession located adjacent to the Crude Oil Tankfarm.

The last stage of the project initiation phase was to determine the local availability of equipment and materials to construct, maintain and monitor the performance of the bioremediation project. It was determined that specialty equipment or materials, such as

the liner, monitoring equipment (moisture, pH and temperature meter) would have to be imported. All remaining materials and equipment were available locally.

## **TREATMENTS**

Four different treatments were identified and evaluated to determine if OBM and drill cuttings could be remediated successfully to acceptable levels under the constraints imposed by the local environmental conditions. The treatment methods were constructed in the following sections:

- Section 1: Straw and Chicken Manure
- Section 2: Straw and Fertilizer
- Section 3: Polyethylene Cover and Fertilizer
- Section 4: Polyethylene Cover and Chicken Manure

Approximately 20 tons of OBM and drill cuttings were placed in each of the four treatment sections. The OBM and drill cuttings that were available for treatment comprised of a dry light brown material with a slight hydrocarbon odor while the new OBM and drill cuttings were a black sludge material with a strong hydrocarbon odor. Details of each of these Sections are presented below:

### **Section 1 Straw and Chicken Manure**

Approximately 30 tons of chicken manure was added. The manure was incorporated into the OBM and drill cuttings using a small tractor and cultivator. A 6-inch layer of straw was then placed on top to provide protection from the heat and to reduce water evaporation.

### **Section 2 Straw and Fertilizer**

Approximately 5 bags (250kg) of Nitrogen-based fertilizer and \_ bag (25 kg) of Phosphorus-based fertilizer were distributed across the cuttings. The fertilizer was incorporated into the OBM and drill cuttings using a small tractor and cultivator. A 6-inch layer of straw was then placed on top to provide protection from the heat and to reduce water evaporation.

### **Section 3 Cover and Fertilizer**

Approximately 5 bags (250kg) of Nitrogen-based fertilizer and    bag of (25 kg) Phosphorus-based fertilizer were distributed across the cuttings. The fertilizer was incorporated into the drill cuttings using a small tractor and cultivator. A 22-mil plastic cover was spread over the drill cuttings and fertilizer. Scrap pipe was used to secure the plastic cover in case of high winds.

### **Section 4 Cover and Chicken Manure**

Approximately 30 tons of chicken manure was added. The manure was incorporated into the drill cuttings using a small tractor and cultivator. A 22-mil plastic cover was spread over the drill cuttings and chicken manure. Junk pipe was used to secure the plastic cover in case of high winds.

## **BIOCELL CONSTRUCTION**

The Bioremediation Pilot Project utilized a biocell approximately 1 hectare in size, which was divided into four approximately equal areas of dimensions 50m x 50m. Each of the treatment was applied to one of four areas. Construction of the biocell utilized local equipment and labor. A bulldozer was used to prepare, level and to construct a one meter high berm around the site. Approximately 3 inches of sand was then placed on top of the site and a 20 mil high density polyethylene liner was installed. Another 6 inches of sand was placed on top of the liner to prevent accidental damage. The old and new OBM and drill cuttings were combined together on site and then spread out on top of the sand.

## **BIOCELL MONITORING**

The biocell was monitored weekly for pH, moisture and salinity and the measurements analyzed to determine water and nutrient requirements. Water was applied as required. Once a week the biocell was aerated by a cultivator pulled by a tractor.

## **RESULTS**

On January 16, 2001 three samples were obtained from the OBM and drill cuttings currently stored at the East Zeit shorebase. The samples were analyzed for the following parameters:

- LEPH (light extractable hydrocarbons, C10 to C19)
- HEPH (heavy extractable hydrocarbons, C19 to C32)
- Phosphates
- Nitrates
- Standard Plate Count (colony forming units/gram (CFU))
- pH
- Moisture

The biocell construction was started in late March and samples were obtained from the soil placed in each section in April 2001 and June 2001.

The initial concentrations of hydrocarbons in the drill cuttings were LEPH (C10-C19) 80,800 to 169,000 mg/Kg and HEPH (C19-C32) 59,800 to 118,000 mg/Kg. This gave a total extractable petroleum hydrocarbon concentration between 140,600 and 287,000 mg/Kg.

**Table 1. Section 1 Straw and Chicken Manure**

Sample Date	Moisture %	pH	Nitrate mg/Kg	Phosphate mg/Kg	Standard Plate Count (CFU/g)	EPH C10-C19 mg/Kg	EPH C19-C32 mg/Kg
11/4/01	11	9.0	22	220		60,900	37,100
20/6/01*	7.5	7.5	20	65	3,395,000	34,300	36,400

\* Average of Section 1A and 1B

#### Section 2 Straw and Fertilizer

Sample Date	Moisture %	pH	Nitrate mg/Kg	Phosphate mg/Kg	Standard Plate Count (CFU/g)	EPH C10-C19 mg/Kg	EPH C19-C32 mg/Kg
11/4/01	8.7	10.6	5	<1		54,300	32,300
20/6/01*	6.3	8.4	16	8	119,750	61,150	51,200

\* Average of Section 2A and 2B

#### Section 3: Cover and Fertilizer

Sample Date	Moisture %	pH	Nitrate mg/Kg	Phosphate mg/Kg	Standard Plate Count (CFU/g)	EPH C10-C19 mg/Kg	EPH C19-C32 mg/Kg
11/4/01	8.7	10.8	4	<1		65,400	37,600
20/6/01*	11.2	9.2	6	6	165	60,800	38,600

#### Section 4: Cover and Chicken Manure

Sample Date	Moisture %	pH	Nitrate mg/Kg	Phosphate mg/Kg	Standard Plate Count (CFU/g)	EPH C10-C19 mg/Kg	EPH C19-C32 mg/Kg
11/4/01	11.2	8.9	15	113		62,220	35,600
20/6/01*	18.7	7.8	10	75	2,510,000	24,900	34,200

On August 30<sup>th</sup>, 2001 the biocells were combined into two segments. Biocell Sections 1 and 4 (containing chicken manure) were combined to form DCS1 and biocell Sections 2 and 3 (containing fertilizer) were combined to form DCS2. Chicken manure was incorporated to the combined sections of DCS2 and the biopiles were allowed to degrade independently and sampled on November 27, 2001.

**Table 2**

Sections 1 and 4

Sample Date	Moisture %	pH	Nitrate mg/Kg	Phosphate mg/Kg	Standard Plate Count (CFU/g)	EPH C10-C19 mg/Kg	EPH C19-C32 mg/Kg
27/11/01	8.1	7.4	8.9	262	22,400,000	15,600	17,500

Sections 2 and 3

Sample Date	Moisture %	pH	Nitrate mg/Kg	Phosphate mg/Kg	Standard Plate Count (CFU/g)	EPH C10-C19 mg/Kg	EPH C19-C32 mg/Kg
27/11/01	6.8	7.4	40	103	2,460,000	23,400	26,000

On April 29, 2003 samples were obtained in the combined Sections. The samples were analyzed following a US test method (TNRCC TX 1005) rather than the British Columbia method that had been used previously. However the range of total hydrocarbons analysed were comparable and therefore considered to be relevant in the reporting of the project results.

**Table 3**

Sections 1 and 4

Sample Date	Moisture %	pH	Nitrate mg/Kg	Phosphate mg/Kg	Standard Plate Count (CFU/g)	EPH C6-C12 mg/Kg	EPH C12-C28 mg/Kg
29/4/03	-	-	-	-	ND	1100	6500

Sections 2 and 3

Sample Date	Moisture %	pH	Nitrate mg/Kg	Phosphate mg/Kg	Standard Plate Count (CFU/g)	EPH C6-C12 mg/Kg	EPH C19-C32 mg/Kg
29/4/03	-	-	-	-	ND	ND	1200

## DISCUSSION

On 16 January 2001 the concentration of hydrocarbons in the drill cuttings ranged from 140,600mg/Kg to 287,000 mg/Kg, which comprised of approximately 30% lower molecular weight hydrocarbons (EPHC10-C19) and 70% (EPH19-32). The bacterial analysis indicated that approximately 2,840 colony-forming units per gram (CFU) of sample were present.

In April, 2001, the four sections of the biopile were established: Section 1 (Straw and Manure); Section 2 (Straw and Fertilizer); Section 3 (Cover and Fertilizer); and Section 4 (Cover and Manure). Each of these sections contained approximately the same concentrations of total extractable hydrocarbons (8 to 11%) with the lighter hydrocarbons to heavier hydrocarbon ratio approximately 1.7:1.

By June 2001, the concentration of total extractable hydrocarbons in Section 1 was approximately 70,700mg/kg (compared to 98,000mg/kg in April) with the ratio of lighter to heavier hydrocarbons reduced to approximately 1:1. The bacterial analysis indicated between 2.2 and 4.5 million CFU (average of 3.4 million) in this Section. In Section 2 there was no degradation of concentrations of hydrocarbons from the April analysis (and the bacterial analysis indicated that an average of approximately 120,000 CFU were present. Similarly, in Section 3, there was no evidence of any significant change in hydrocarbon concentrations compared to the April analysis. The bacterial analysis indicated only 165 CFU. Section 4 showed the highest rate of biodegradation with the total extractable hydrocarbons concentration at 59,100mg/kg and a ratio of lighter to heavier molecular weight hydrocarbons at 1 to 1.37. The bacterial analysis indicated the presence of 2.5 million CFU.

In November 2001, after Sections 1 and 4 (chicken manure only) had been combined to form DCS1, the concentration of extractable hydrocarbons was approximately 33,000 mg/kg compared to an average of 64,900 mg/kg in June, and an estimated average concentration of 97,910 mg/Kg in April. The bacterial analysis indicated that 22.4 million CFU/g were present, which is indicative of a high rate of bacterial activity. In this section the ratio of lighter to heavier molecular weight hydrocarbons was 1 to 1.12. In DCS2, (combination of Sections 2 and 3 plus the addition of chicken manure) the concentration of hydrocarbons was approximately 49,400 mg/kg compared to an average of 105,800 mg/kg in June. The bacterial activity had increased to 2.5 million CFU/g, which, although high, is still an order of magnitude below the DCS1 sample. The ratio of lighter to heavier molecular weight hydrocarbons at 1 to 1.11.

In April 2003, laboratory analysis of total petroleum hydrocarbons in the soil samples obtained combined Sections 1 and 4 was approximately 7,600 mg/kg compared to 33,000 mg/kg in November 2001. In combined Sections 2 and 3, concentrations of total

petroleum hydrocarbons were 1200 mg/kg compared to 49,400 mg/kg in November 2001.

## **CONCLUSIONS**

Initially the biopiles using manure had a much higher rate of biodegradation of the hydrocarbons present. The biopile that underwent nutrient addition in the form of fertilizer did not show any evidence of biodegradation, however evidence of accelerated degradation since the incorporation of manure is shown in the November 2001 and April 2003 laboratory analysis. It is interesting to note that the status of Sections 2 and 3 in November is comparable to Sections 1 and 4 in June in terms of both hydrocarbon concentration and colony forming units in the bacterial analysis. Also noteworthy is the April 2003 laboratory analysis that shows Sections 2 and 3 has a higher biodegradation rate for both lighter and heavier hydrocarbons compared to Sections 1 and 4. This is probably due to the nutrient limitation of the chicken manure alone.

Based on these results it has been determined that bioremediation in an arid climate can be achieved. To accelerate the biodegradation rate of both lighter and heavier hydrocarbon both microbial inoculation and nutrient additions are required. .

Devon's Egypt operations have chosen bioremediation using a combination of inorganic fertilizer, straw cover and microbial inoculation using chicken manure as the waste management method for drilling programs requiring the use of oil-based drilling mud.