RECENT BIOREMEDIATION RESULTS ON OIL SPILLED DURING THE 1991 GULF WAR[1]

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ABSTRACT

Over thirteen years ago, Iraqi soldiers caused the release of over 10 million barrels of oil into Arabian Gulf waters from various sources. The oil impacted the majority of the western Gulf shoreline, estimated at over four hundred miles. Coastal development is having to deal with oil which was buried, stock-piled, or otherwise left in place. One such development is underway at Al Khiran (southern Kuwait) where oil is within planned construction areas for public beaches, housing lots, a marina, and channels. Although the oil is weathered and generally considered non-toxic (based on chemical analyses below), expanses of it pose physical and esthetic problems for construction and human use of the areas. Tests were performed using various means of treating this oil, and the results are given herein.

A variety of bioremediation methods was tested, including the use of products from four companies, selected at random from the oil spill chemical industry (U.S. and abroad). All four were bacterial powders, with nutrients included or added separately, applied according to manufacturers' specifications. Test plots were on mildly contaminated soil (33 mg/kg total hydrocarbons) which had oil mixed throughout. Plots were located in the upper intertidal zone, where they were exposed to minimal (<30 cm), diurnal, high tide flooding, and the research site was protected from wave and wind action by a levee. Extreme conditions at the sites included high temperatures, lack of rainfall, and flushing by high salinity seawater (40 parts per thousand salt).

Sites were sampled before treatment, and at various times beginning 44 days after treatment. Composite samples were collected from each test plot and analyzed for total petroleum hydrocarbons (TRPH), and for three hydrocarbon ranges: C8-C10, C10-C28, and C28-C40. Results showed no significant reduction in total hydrocarbons by any product, compared to pre-treatment levels. Aggressive physical tilling of contaminated soils at a second site provided some reduction in total hydrocarbons during this period. Various methods were tried in the next phase of testing, including additional product exposure time, increased tilling, and screening. The results provide guidelines for the use of chemical products and physical treatments, in extreme coastal conditions, for the treatment of weathered hydrocarbons.

INTRODUCTION

The southern coastline of Kuwait is the location of an extensive inland canal and development project, call Pearl City (Ealey et al., 1989), located in Al-Khiran (Fig. 1). Construction of canals and housing sites resulted in conflicts with oil stranded by the 1991 Gulf War, which found its way into existing channels. Two sites were located for testing of bioremediation techniques (Fig. 1).

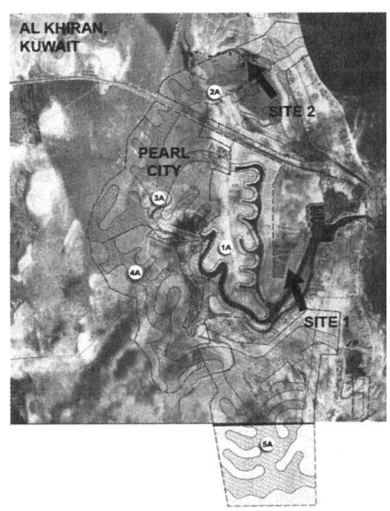

FIGURE 1. LOCATION OF PEARL CITY AT AL-KHIRAN, SOUTHERN KUWAIT, SHOWING TWO REMEDIATION TEST SITES AND 5 PHASES OF THE DEVELOPMENT IN PROGRESS.

METHODS

First Test Site

A section of oiled shoreline was located along lower Khor–Al Mufateh (Fig. 2). The site had been traversed by equipment (trucks, dozers) and a berm was constructed on one side. It was important to deal with this site to determine if it presented a contamination risk or a conflict to the development. Chemical analyses of contaminated soils are shown in Table 1. Results showed relatively low levels of hydrocarbons which did not pose a risk to the environment. The US contamination level requiring cleanup is 340 mg/kg (based on EPA TRPH standards using Florida FL-PRO analysis, from AEHS, 2000), although the half-life (time at which 1/2 of the oil is gone) of these aging hydrocarbons in aerated soil is expected to be 540 days (OEHHA, 2000). This indicates that while the levels are not toxic, oil staining will persist for several more years.

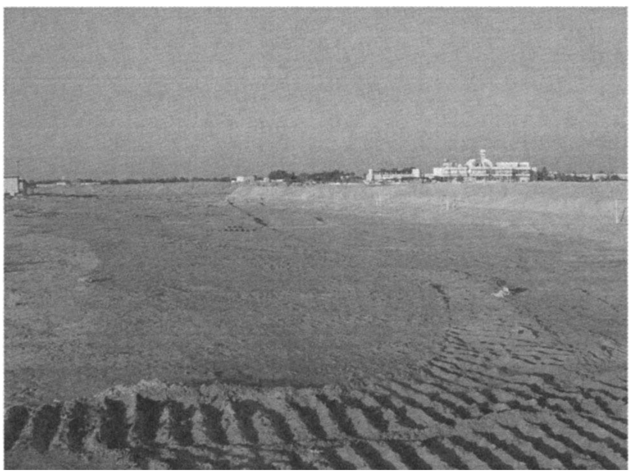

FIGURE 2. SECTION OF OILED SHORELINE LOCATED ALONG LOWER KHOR–AL MUFATEH.

Table 1. Results of hydrocarbon analyses of a pre-test soil sample at the Khor Al-Mufateh site (carbon chain size breakdowns do not add up to total because not all hydrocarbons are included in the total).

PARAMETER	RESULT	UNITS
Total Hydrocarbons (TRPH)	33.5	mg/kg
C8-C10 Hydrocarbons	<2	mg/kg
C10-C28 Hydrocarbons	2.55	mg/kg
C28-C40 Hydrocarbons	7.97	mg/kg

On February 12, 2004, four types of oil remediation chemicals were applied to 4 test areas chosen at random on the site. The test plots were circles with marked, flagged stakes in the center, each measuring $3m^2$ in area (Fig. 3). The test plots were raked and the chemicals were applied according to manufacturers' instructions. The areas were re-sampled 3 months later.

Second Test Site

In the environmental impact assessment of Khor Al Ama, a larger area of oil was disclosed. A dumping area at the upper reaches of the Khor had spread into the channels and marshes (Fig. 4). The contamination had also spread into a blue-green algae mat which existed in the upper Khor (Fig. 5).

FIGURE 3. TEST PLOT FOR TREATMENT OF OIL CONTAMINATION AT THE KHOR AL-MUFATEH SITE.

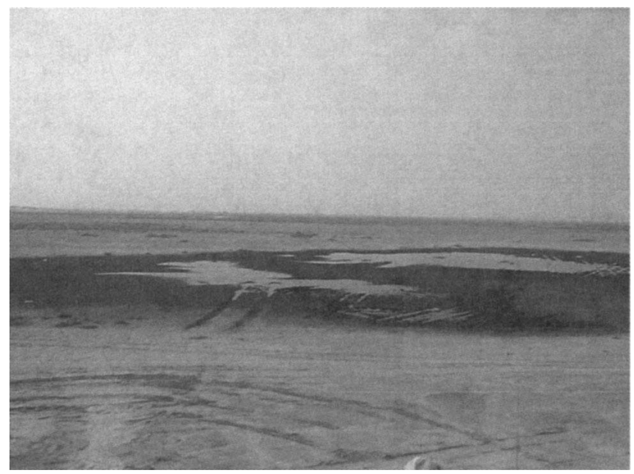

FIGURE 4. VIEW OF MAIN OIL DUMPING AREA IN UPPER KHOR AL AMA.

FIGURE 5. VIEW OF BLUE-GREEN ALGAL MAT, FOUND TO HAVE SOME OIL CONTAMINATION, IN UPPER KHOR AL AMA.

Soil samples were taken from the substrates down-gradient of this area and analyzed as above, and the results are given in Table 2. Results were low for hydrocarbons and indicated that there was no risk to the environment. However, as with the Khor Al-Mufateh site, there is a long-term potential for staining by these black residues.

Table 2. Results of hydrocarbon analyses of soil samples from the Khor Al-Ama site (carbon chain size breakdowns do not add up to total because not all hydrocarbons are included in the total).

PARAMETER	RESULT	UNITS
Tidal Flat Sample		
Total Hydrocarbons TRPH	18.7	mg/kg
C8-C10 Hydrocarbons	<2	mg/kg
C10-C28 Hydrocarbons	<2	mg/kg
C28-C40 Hydrocarbons	5.10	mg/kg
Algae Sample		
Total Hydrocarbons TRPH	15.3	mg/kg
C8-C10 Hydrocarbons	<2	mg/kg
C10-C28 Hydrocarbons	<2	mg/kg
C28-C40 Hydrocarbons	5.13	mg/kg

For this site, a test area was coarsely raked (Fig. 6) and then hand raked weekly for two months, after which samples were collected and sieved through #25 screen (<0.5mm mesh size). Pre-screened and screened samples were analyzed.

FIGURE 6. TYPE OF RAKING PERFORMED ON LIGHTLY OIL-CONTAMINATED AREAS.

RESULTS

Results of the oil remediation chemicals are given in Table 3. Brand names are not given in the interest of scientific objectivity. As shown, the chemicals had little effect over the six month trial period. For final treatment of this area, chemical "D" was applied to the entire site and raked in. The area was later covered with clean fill.

Table 3. Oil remediation chemical test results.

Test Plots #	Chemical Code Name	Pre-test Analysis Total Hydrocarbons	Post-test Analysis Total Hydrocarbons
1	A	33.5 mg/kg	33.4 mg/kg
2	B	33.5 mg/kg	36.8 mg/kg
3	C	33.5 mg/kg	34.6 mg/kg
4	D	33.5 mg/kg	32.3 mg/kg

Results of the raking and screening tests are given in Table 4. As shown, screening had a profound effect on hydrocarbon separation and removal. The sieved sand was clean and contamination was minimal when compared to the original raked, contaminated sample (Fig. 7). Collected hydrocarbon-dense material was incinerated.

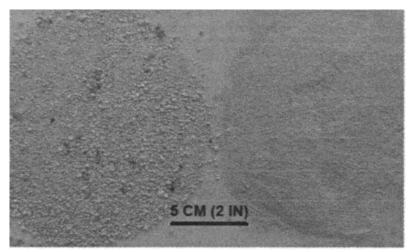

FIGURE 7. CONTAMINATED MATERIAL BEFORE AND AFTER SIEVING, UN-SIEVED MATERIAL ON THE LEFT AND SIEVED SAND ON THE RIGHT.

DISCUSSION AND CONCLUSIONS

The failure of bioremediation chemicals to degrade the 13-year old oil at the site is probably a function of the age of the oil and the field conditions rather than the abilities of these chemicals which have a proven track record. Those who have worked on the Gulf war spill stress aeration and increasing surface area (Michel, pers. comm.) as best means of enhancing degradation of this oil. The use of raking to break up larger asphalts, followed by screening to remove smaller, denser particles, can greatly enhance this process.

The cost of large scale sand screening is not necessarily prohibitive, since this is a common practice at sand and rock

Table 4. Results of raking and screening of oil-contaminated soils. Hydrocarbons are broken down into number of carbons (carbon range), and total hydrocarbons are derived by summation of all fractions. BDL = below detection limits.

Sample	Percent of sample	C-8 – C10	C10 – C28	C28- C40	TOTAL HYDROCARBONS
Contaminated sand	100	BDL	111	235	346
Sand passing sieve	75.3	BDL	16.1	24.6	40.7
Material collected on sieve	24.7	BDL	501	766	1,267

quarries, and large amounts of material can be processed by these facilities. The sieved, high quality sand can be used in construction while the contamination is incinerated or used in asphalt, tars, or similar products.

BIOGRAPHY

Dr. Bart Baca is a marine biologist with almost 25 years of experience in oil spill research. He has responded to many large and historic spills and he has published numerous articles on fate and effects. His research focuses on long-term effects on mangroves, seagrasses, and shorelines throughout the world.

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