Comparison of Site Characterization of Contaminated Soil in South & East Kuwait Oil fields

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Kuwait Geographical Information

- The State of Kuwait is located in the northeast corner of the Arabian Peninsula.

- Kuwait is one of the smallest countries in the world in terms of land area.

- The flat, sandy Arabian Desert covers most of Kuwait.

- Kuwait includes several offshore islands, the largest of which is Bubiyan, near the Iraqi border.
After the Gulf war, in February 1991, Kuwait’s oil wells were damaged and set on fire, resulting in oil contamination of the land.

Environment Contamination occurred from oil spreading over the land surface and penetrated the soil to varying depths forming oil lakes.

These large oil lakes and other contaminated features still exist today in KOC field with an estimated volume of 26 million cubic meters.

This Unique Programme is currently the largest environmental inland cleanup in the world.
The following Environmental Claim elements were awarded to KOC by United Nations Compensation Commission under Decision 258.

- **Claim No. 5000259**
  (Coastal & Marine Resources)

- **Claim No. 5000450**
  (Remediation of areas in and around wellhead pits and Tarcrete)

- **Claim No. 5000454**
  (Remediation of areas damaged by oil lakes, oil-contaminated piles, oil trenches & oil spills)
Areas covered with black liquid (highly weathered oil) and semi solid oil saturated material resulting from oil flow damaged oil wells.

Occur in areas where large liquid oil accumulated because of local topography and micro relief.

Investigations revealed that the average depth of oil contamination in the wet contaminate areas is approximately 63 cm.
Wet Oil Contaminated Soil

- Oily liquid sludge - Layer 1
- Heavily contaminated layer below the sludge
- Visibly contaminated soil - Layer 2
- Visibly uncontaminated soil
Dry Oil Lakes

- Dry oil lakes are generally found in shallow depressions and/or flat areas.
- The dry contamination areas cover almost 100 square Km of the desert, with an average depth of approximately 25 cm.
Dry Oil Contaminated Soil

Heavily contaminated surface layer -1

Visibly contaminated layer -2

Visibly uncontaminated layer
Discussion of Data Analysis for Different decades

1. Historic Data in S&EK fields:
   - In 2003, Kuwait’s monitoring and assessment consultants analysed data and performed mapping and analytical sampling surveys to delineate the extent of the oil lakes (wet and dry).
   - The sampling survey involved collecting soil samples in to different depths/ layers (layer 1, contaminated surface; layer 2, subsurface contaminated layer).
   - A total of approximately 850 samples were collected and analysed from various contaminated features at various locations in South and East Kuwait (S&EK).
Discussion of Data Analysis for Different decades

Historic Data (CIC-2002) in S&EK fields:

Table 1: Minimum, maximum & Mean for TPH level in Layers-1&2 of Wet and Dry oil lakes

<table>
<thead>
<tr>
<th>Material Type / Analysis</th>
<th>Minimum (mg/kg)</th>
<th>Maximum (mg/kg)</th>
<th>Geometric Mean (mg/kg)</th>
<th>Arithmetic Mean (mg/kg)</th>
<th>Standard Deviation (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wet Oil Lake</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layer 1</td>
<td>64,700</td>
<td>163,000</td>
<td>106,286</td>
<td>113,850</td>
<td>7,564</td>
</tr>
<tr>
<td>Layer 2</td>
<td>14,600</td>
<td>30,600</td>
<td>21,614</td>
<td>22,600</td>
<td>986</td>
</tr>
<tr>
<td><strong>Dry Oil Lake</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layer 1</td>
<td>11,300</td>
<td>353,000</td>
<td>62,103</td>
<td>92,990</td>
<td>30,887</td>
</tr>
<tr>
<td>Layer 2</td>
<td>1100</td>
<td>83,000</td>
<td>16,435</td>
<td>21,541</td>
<td>5,106</td>
</tr>
</tbody>
</table>
2. Limited Scope Investigation in S&EK fields

- KOC conducted a limited soil characterization study in November and December 2014.

- The focus of the limited investigation was to characterize soils that may be suitable for treatment technologies and to update the current understanding of soil contaminants levels and refine the aerial and vertical extent with carbon brandings to support remediation strategy.

- The sampling was focused on features known as ‘Dry Oil Lakes’ and ‘Wet Oil Lakes’ features. The summary data for TPH analysis has been split into feature type, (i.e., wet oil and dry oil lake features), and into different layers: Layer 1 and Layer 2 which represents underlying visually clean soils.
## Discussion of Data Analysis for Different decades

### Limited Scope Investigation – Burgan in South East Kuwait:

<table>
<thead>
<tr>
<th>Material Type / Analysis</th>
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<tr>
<td><strong>Wet Oil Lake</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Layer 1</td>
<td>94,835</td>
<td>166,171</td>
<td>133,373</td>
<td>135,557</td>
<td>25,310</td>
</tr>
<tr>
<td>Layer 2</td>
<td>11,585</td>
<td>87,450</td>
<td>32,847</td>
<td>39,749</td>
<td>24,840</td>
</tr>
<tr>
<td><strong>Dry Oil Lake</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layer 1</td>
<td>718</td>
<td>126,811</td>
<td>17,576</td>
<td>27,847</td>
<td>10,271</td>
</tr>
<tr>
<td>Layer 2</td>
<td>9,923</td>
<td>35,126</td>
<td>23,660</td>
<td>28,507</td>
<td>4,847</td>
</tr>
</tbody>
</table>
3. Recent Petroleum Hydrocarbons investigation in S&EK fields

- The most recent environmental analytical data relates to total petroleum hydrocarbon (TPH) analysis conducted during the period of 2016 to 2017.

- The samples were collected from different locations layer 1 & layer 2 in SEK Burgan fields.

- A total of approximately 200 soil samples were collected and analysed from various soil feature locations in South and East Kuwait (S&EK).
Recent Petroleum Hydrocarbons Investigations in S&EK fields:

<table>
<thead>
<tr>
<th>Material Type / Analysis</th>
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<tr>
<td><strong>Wet Oil Lake</strong></td>
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</tr>
<tr>
<td>Layer 1</td>
<td>305,816</td>
<td>624,513</td>
<td>466,424</td>
<td>480,068</td>
<td>13,644</td>
</tr>
<tr>
<td>Layer 2</td>
<td>73,941</td>
<td>169,045</td>
<td>131,966</td>
<td>13,6521</td>
<td>4,555</td>
</tr>
<tr>
<td><strong>Dry Oil Lake</strong></td>
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<td></td>
</tr>
<tr>
<td>Layer 1</td>
<td>1,074</td>
<td>326,421</td>
<td>62,440</td>
<td>89,456</td>
<td>27,016</td>
</tr>
<tr>
<td>Layer 2</td>
<td>9,866</td>
<td>203,760</td>
<td>30,310</td>
<td>40,052</td>
<td>9,742</td>
</tr>
</tbody>
</table>
TPH Comparison for Different decades

Wet Oil Lakes (WOL) in S&EK fields:


Layer 1
Layer 2

Data 2003  Data 2014  Data 2016
TPH Comparison for Different decades

Dry Oil Lakes (DOL) in S&EK fields:

![Dry Oil Lake TPH Comparison Datas 2003, 2014 & 2016](image)
Analysis and Conclusion

During the Gulf War in 1990, highly contaminated oil lakes were formed covering a large area of Kuwait’s desert area. As a result of oil presence, soil properties were negatively affected.

No natural degradation has been observed in all crude oil constituents in terms of TPH levels in both WOL and DOL features. Although considerable evaporation, photo-oxidation and weathering processes have taken place since the war, the TPH levels have increased drastically.

The graphs indicate there are upward trends of TPH levels over these periods and which cannot be easily explained from initial to the latest studies. However, it is speculated that multiple factors could have contributed to these observations:
  * The depths of sampling collection
  * Variable laboratory analysis methods, data interpretations
  * Multiple laboratories used and/or under-estimations of TPH levels during initial soil studies.
Thank you
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