

Hydrocarbon sludge treatment in upstream oil and gas industry of Kuwait– Case Study

24th International
Petroleum & Environmental Conference
San Antonio, TX
30 Oct'17 – 1 Nov'17

Krishna Vangala
Soil Remediation Group
Kuwait Oil Company



Co-Authors :
Mansour Al-Khareji, Soil Remediation Group
Kuwait Oil Company

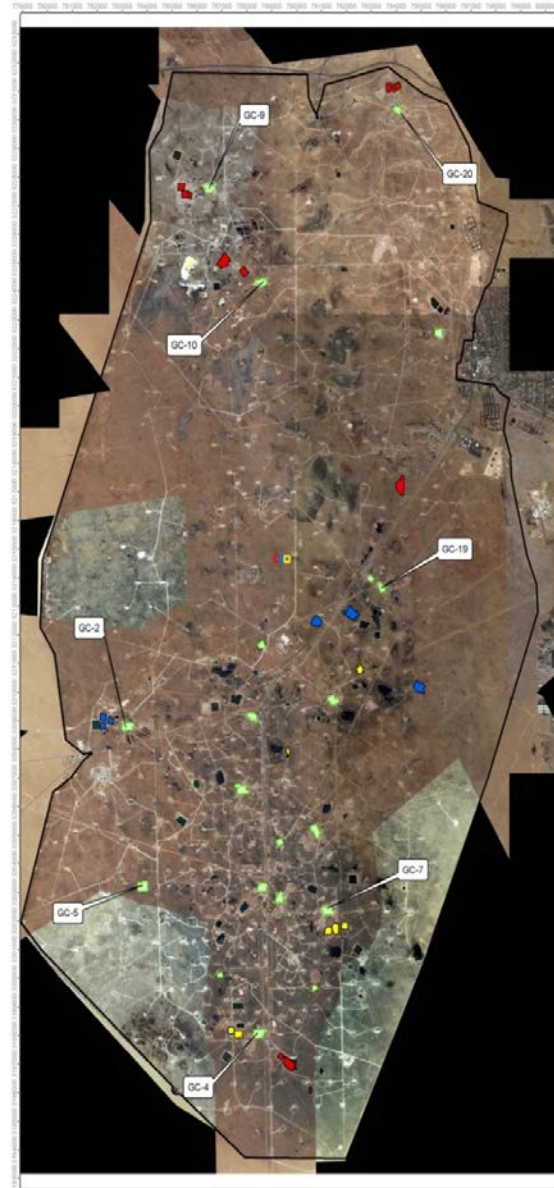
Regional Settings for the Sludge Treatment

- Harsh climate (0-58 °C)
- High Wind speeds
 - Sand erosion
 - Sand storms
- Prior projects
 - Limited pilots/demo studies
 - No in-country vendors/labs
- Unfavorable site conditions
 - Heavier fractions/Ashphaltin
 - Ordnance clearance
 - Site characterization



THE ISSUE

- ◆ Historical legacy of KOC Oil & Gas Exploration & Production operations have given rise to environmental pollution and damage to the natural desert environment.
- ◆ Typical non-operational redundant polluted features include the following:
 - ◆ Effluent Pits (produced water)
 - ◆ Sludge Pits (recovered oil from spills/leaks)
 - ◆ Contaminated Soil Piles (oil soaked soil)
 - ◆ Gatch Quarry Pits (construction purposes)
- ◆ In addition, UXO remnants of war are potentially associated with polluted areas.



CONTAMINATED FEATURES



Effluent Pit



Effluent Pit



Effluent Pit



Gatch Pit



Sludge Pit



Contaminated
Soil Pile

REMEDIATION SPECIFICATION

Primary Ecotoxic RS

- Soil within top 1.5m below finished grade;
 - Total PHC \leq 5,580 mg/kg;
 - PAHs & BTEX compound specific;
 - Heavy Metals

Alternative Ecotoxic RS

- Soil within top 1.5m below finished grade;
 - Total PHC \leq 10,000 mg/kg;
 - Salinity (\leq 4.5 dS/m, SAR 12); and

Commercial / Industrial RS

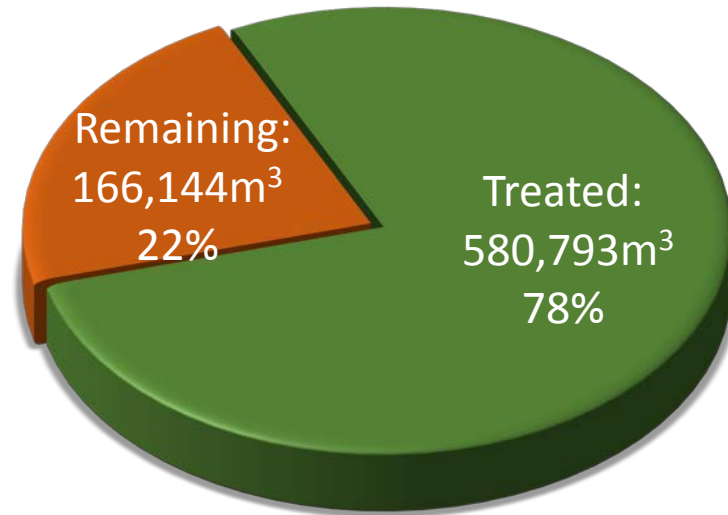
- Soil below 1.5m of finished grade;
 - Total PHC \leq 30,000 mg/kg; and
 - PAHs compound specific.

Remediation of Oil Contaminated Soils



Soil Washing

Total Volume: 746,937m³



Thermal Desorption



Bio-Remediation



Soil Remediation Completion

Gatch Pit A1 - Before



Effluent Pit C1- Before



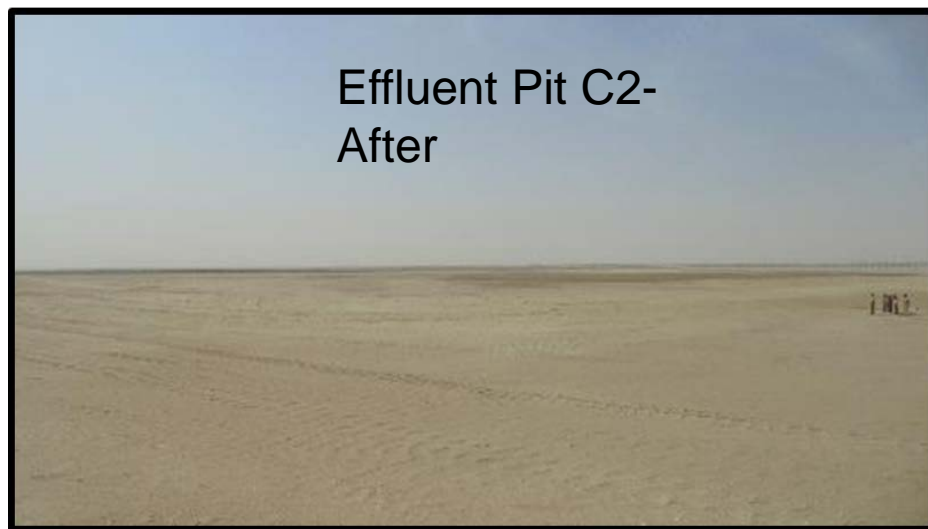
Gatch Pit A1 - After



Effluent Pit C1- After

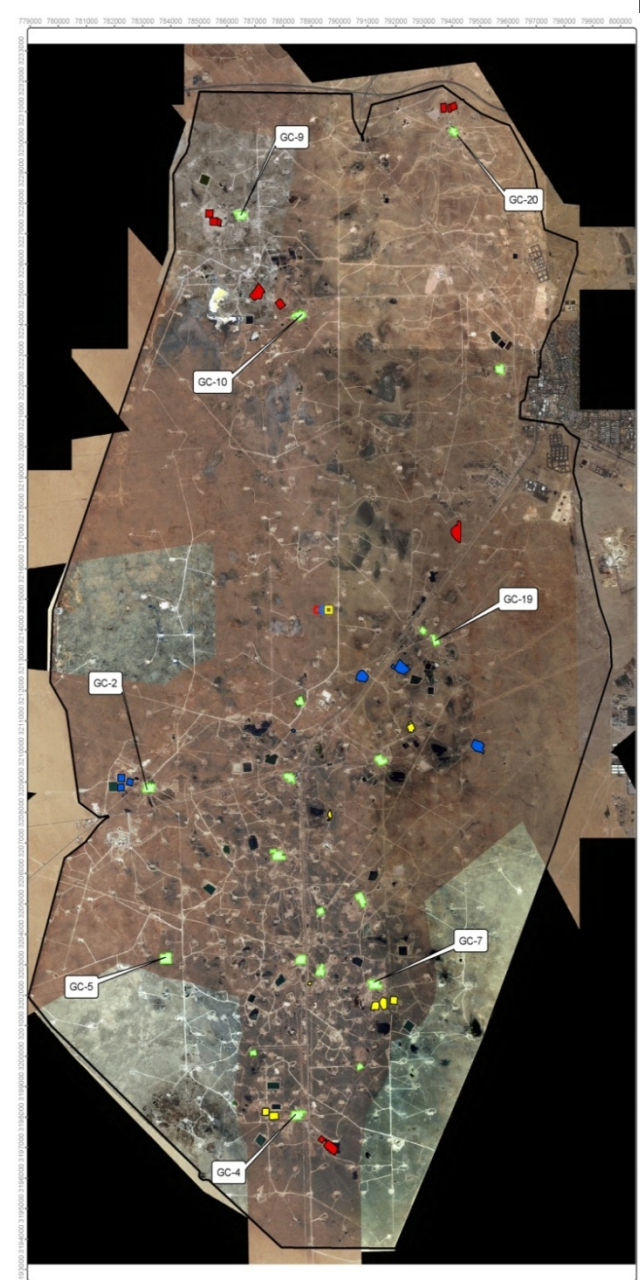


Soil Remediation Completion



PREVIOUS PRESENTATIONS

- ◆ Presented previous papers in last seven IPEC conferences which dealt with undertaken remediation works in KOC.
- ◆ The remediation works had commenced in year 2012 :
 - ◆ Remediation Program overview
 - ◆ Soil Remediation
 - ◆ Oil recovery
 - ◆ Results
 - ◆ Lesson Learnt
 - ◆ Way forward



Characteristics of Sludge Pit Features



Sludge Pits

- Large Size with a size ranging from :
- 80m * 100 m
- 300 m X 300 m
- Depths ranging from 1-3m
- 33 sludge pits and presence of sludge in other pits as well



- Earthen bunded features
- The Pits consists of free/floating oil on the surface, saline effluent underneath and oily sludge at the base of the feature.
- The pits arise from the need to dispose of waste/surplus oil resulting from shutdown, workover and maintenance operations of well heads and pipelines etc..



Dry & Wet Sludge



Dry Sludge Tarcrete Crust



Dry Sludge



Sludge & Oil



Sludge & Oil Holding Pit



Sludge Melting



Stockpiled Sludge



Tarcrete



Wet Sludge-1



Wet Sludge-2



Wet Sludge Removal-1



Sludge Removal-2

Sludge Volumes

	BOQ Sludge Volume m ³	Site Characterisation Sludge Volume m ³
Lot A	77,900	24,147
Lot B	7,870	6,518
Lot C	33,450	9,951
Totals	116,220	40,616

Note : Oil generated from sludge is part of sludge treatment. Oil handed back to the Company from sludge treatment must meet the oil standard of $\leq 20\%$ BS & W.

Classification of the Contamination & Sludge Scope

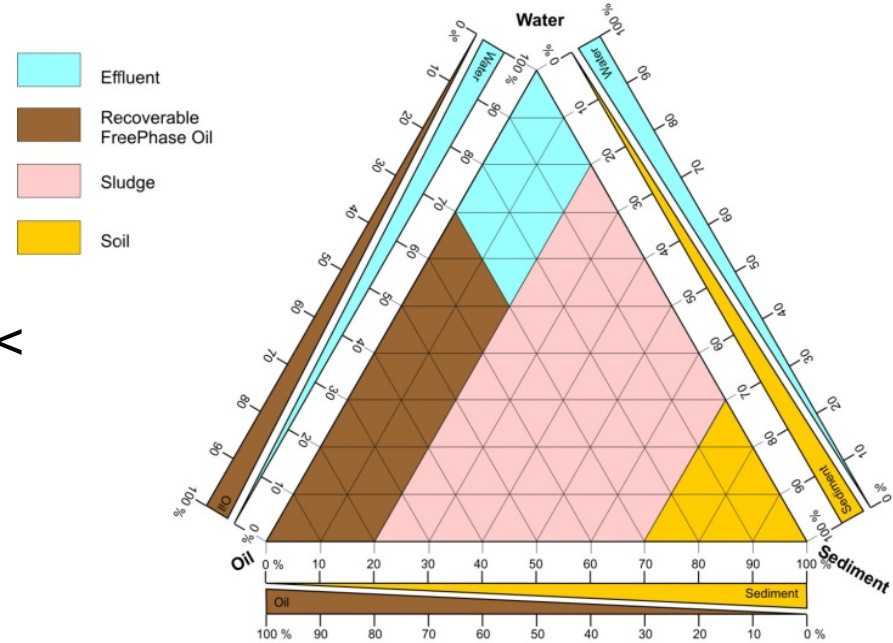
Classification of Contamination :

- ◆ Free phase oil
- ◆ Effluent Water
- ◆ Sludge
- ◆ Contaminated Soil

➤ **Sludge:** sediments > 20% vol and < 70% vol, oil and/or water between 30% vol and 80% vol.

Scope of Work

- To conduct treatment of sludge following crude oil recovery, including physical stabilization, if required, by appropriate remediation techniques to achieve appropriate Remediation Standards (RS)
- In addition, it was expected to undertake all treatment optimization trials to ensure the proposed remedial methods are suitable.



Sludge Characteristics

	HEM C6-C35 Avg (mg/kg)	HEM >C16-C35 Avg (mg/kg)	HEM >C35-C90 Avg (mg/kg)	Total HEM Avg (mg/kg)	Total HEM Max(mg/kg)
Lot A	26,400	25,400	277,000	481,000	752,000
Lot B	31,800	27,000	255,000	252,000	352,000
Lot C	106,000	206,000	368,000	775,000	866,000

Particle Size Analysis Results of Sludge Samples

	Gravel+Sand > 0.063 mm	Silt 0.063 – 0.002 mm	Clay < 0.002 mm
Lot A	76.00 %	24.00 %	0 %
Lot B	79.87 %	18.63 %	1.50 %
Lot C	76.53 %	23.47 %	0 %

Sludge Characteristics

Sample ID	BS&W (Vol%)	Oil Content (Vol%)	Density (g/cm)	API	Viscosity (cSt)
98296828-1	76.6	23.4	0.96287	14.36	1205
98586871-1	72.7	28.3	0.96071	14.69	1703
97736740-1	21.8	78.2	0.95884	14.97	811
97266947-1	62.4	37.6	0.96741	13.69	2598
95507034-1	85.2	14.8	0.96217	14.47	1778
96257151-1	55.4	44.6	0.96353	14.26	6720

Soil Remediation Trials (1 to 4)



Indirect TDU (Trial 1)



Bioremediation (Trial 2)



Direct TDU (Trial 3)



Bioremediation (Trial 4)

Sludge Treatment Methods- Trail 1

Description	Unit	Batch 1	Batch 2	Batch 3
PHC levels before mixing	mg/kg	145,000 to 190,000		
Mix Ratio (Sludge/Soil)	-	1.5:1	1:1.5	1.5:1
PHC levels post mixing	mg/kg	115,000	78,200	84,100
Total Volume	m3	523	728	2,115
Sludge Volume	m3	314	291	1,269
Treatment Rate	m3/hr	5.0	5.0	5.0
Treated Material	-	Sludge & Soil	Sludge & Soil	Sludge & Soil
Technology Used	-	Indirect TDU	Indirect TDU	Indirect TDU
Final PHC Concentration	mg/kg	1,640	1,400	1,790
Observations	-	ITDU generated oil and oily sludge as by-product; frequent shut downs due to blockages by contaminated materials		
Results	-	Stopped treating sludge using ITDU since no technology in place to treat by-product		

Sludge Treatment Methods- Trail 2

Description	Unit	Batch 1	Batch 2	Batch 3
PHC levels before mixing	mg/kg	65,800 to 95,000		
Mix Ratio (Sludge/Soil)	-	None	None	1:1
PHC levels post mixing	mg/kg	88,400	65,800	46,400
Total Volume	m3	530	2,400	4,479
Sludge Volume	m3	530	2,400	2,400
Treatment Rate	m3/hr	188 treatment days	137 treatment days	65 treatment days
Treated Material	-	Sludge	Sludge	Sludge & Soil
Technology Used	-	Bio-remediation	Bio-remediation	Bio-remediation
Final PHC Concentration	mg/kg	88,400	65,800	6,640
Observations	-	PHC levels too high to initiate microbial growth.		PHC below 5% only can be treated using Bio
Results	-	Abandoned trial on unblended sludge.		Blended option proved successful.

Sludge Treatment Methods- Trail 3

Description	Unit	Batch 1	Batch 2	Batch 3
PHC levels before mixing	mg/kg	145,000 to 190,000		
Mix Ratio (Sludge/Soil)	-	1:1	2:1	1:2
PHC levels post mixing	mg/kg	123,300	77,800	56,250
Total Volume	m3	2,640	355	600
Sludge Volume	m3	1,320	236	200
Treatment Rate	m3/hr	4.4	0.9	1.1
Treated Material	-	Sludge mixed with Treated Soil in Soil Washing Unit		
Technology Used	-	Direct TDU2	Direct TDU3	Direct TDU3
Final PHC Concentration	mg/kg	1,060	360	370
Observations	-	Low Sludge Treatment Rate		
Results	-	Continuing Batch-1 but abandoned Batch 2 & 3 in TDU 3		

Sludge Treatment Methods- Trail 4

Description	Unit	Batch 1	Batch 2	Batch 3
PHC levels before mixing	mg/kg	145,000 to 190,000		
Mix Ratio (Sludge/Soil)	-	1:25	None	None
PHC levels post mixing	mg/kg	84,500	48,400	43,800
Total Volume	m3	26	25	25
Treatment Rate	m3	83 treatment days	83 treatment days	83 treatment days
Treated Material	m3/hr	Sludge & Soil	Filter Cake	Soil
Technology Used	-	Bio-remediation	Bio-remediation	Bio-remediation
Final PHC Concentration	mg/kg	35,000	12,400	48,300
Observations	-	No PHC reduction for 56 days	Moderate degradation	No Reduction
Results	-	Although trial results for Sludge/Soil blend and Contaminated Soil were barely encouraging, decided to continue bio-remediation for all blend types		

Sludge Treatment Summary

Trial 2

- Sludge and Blended sludge
- Bio
- Unsuccessful beyond 5% PH

Trial 1

- Blended sludge in ITDU
- Blockages
- Unsuccessful

Sludge Treatment Summary

Trial 3

Sludge mixed with
Treated Soil

Direct TDU
Low Treatment
Rate

Trial 4

Sludge, Filter Cake
& Soil

Bioremediation
No meaningful
degradation

Sludge Proposals

Technology

- Limited commercial technologies

Byproducts

- All of them generating Byproducts

Large scale experience

- Not available and seen missing info

Conclusion

Extremely difficult material to Treat

No proven technology barring TDU (Very low capacity)

Complete solution for sludge (oil, byproducts) yet to be seen

Landfill option is considered



Hydrocarbon sludge treatment in upstream oil and gas industry of Kuwait– Case Study

Thank you
Q & A

