

The Remediation of Oil Contaminated Soil in Kuwait

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Abstract: This paper describes KERP planned strategy and actual works conducted to remediate 26 million cubic meters of contaminated soil in North and South Kuwaiti Oil Fields after the aggressive Iraqi invasion in 1990. KERP remediation strategy has been modified based on comprehensive Site Soil Characterization (SSC) reports of Consortium of International Consultants (CIC 2003); which was verified through special SSC works completed in North and south Kuwait Excavation and Transportation Projects (NKE&T and SKE&T) and various KERP related SSC activities. The strategy modification involves reducing landfill volume to less than 5.0 million m³ by implementing comprehensive remediation techniques which, include natural degradation of residual contamination of Tarcrete at TPH levels of 1-2%, bio-treatment at 2-7%, remediation technologies at 7-20%, re-use of high energetic good quality oil and sludge at high TPH levels of 10-20% and landfilling of difficult to treat soil. Best available and approved technologies combined with best feasible and cost-effective technologies drive the remediation strategy listed above. ⁴KERP contaminated features consist of Dry and Wet Oil Lakes, Contaminated Piles, Tarcrete, WHPs, and Coastal Trench and Deposits. The last two features were totally remediated by excavating, transporting and disposal of the contaminated soil in newly constructed landfills in the south and north Kuwait through NKE&T and SKE&T Projects. However, Tarcrete physical and chemical characteristics revealed no toxicity, fragile, dry, and thin crust feature with no harm to exclude from remediation program. The Program tackled several challenges related to 100% UXO survey and clearance, climate conditions limiting working hours, and spread of contamination over huge areas, as well as executing the site works with massive earth movement equipment and personnel from various subcontractors is a challenge itself. However, collaborative efforts of various stockholders such as KOC, SRP-II, SRS, PMC, local contractors, and KNFP are minimizing risks during the execution.

Key words: Kuwait environmental remediation program, unexploded ordinance, site soil characterization, well head pit, Kuwait National Focal Point, unexploded ordnance

1. Introduction

Under Kuwait Environmental Remediation Program (KERP), Kuwait Oil Company (KOC) being considered the major stakeholder with funds awarded to approx. \$3 Billion considering being the holder of the larger environmental damage. KOC is responsible for implementation of several projects for the remediation of oil-contaminated soil within KOC oilfields damaged by Iraqi invasion against Kuwait and 1991 Gulf War. Numerous oil wells and other oilfield infrastructure was damaged or destroyed at the end of the Gulf War [1]. This resulted in numerous oil

well fires and broken oil pipelines. Approximately 20-25 million barrels of ignited crude oil spilled across the land surface and the ignited oil wells were extinguished using 12 billion gallons of seawater collected in artificial pounds to control the fire. Different types of contamination features were derived from either airborne deposition of crude oil, overland flow or earth moving activities used to mitigate crude oil migration, as described below.

The program involves a large-scale environmental remediation and restoration undertaking funded by the United Nations, and carries high visibility and importance, locally and internationally. Quantity reserved for the remediation is estimated approximately 26 million cubic meters of highly/visually contaminated soil (with total

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petroleum hydrocarbon concentrations greater than 19.2%) covered an area encompassing approximately 114 square kilometers.

The original recommended strategy by the UNCC and Consortium of International Consultants CIC was to excavate the contaminated wet and dry soil, mix it to a certain ratio to make it transportable and to excavate 17 engineered landfills to contain the materials. In view of Kuwait, that was not the best option considering the contaminated materials will remain untouched and the loss of land due to the space required building the landfills leaving a poor legacy to future Kuwaiti generations.

In 2012 a series of alternatives to the landfills were identified but still uncertainties remains unsolved. And due to lack of references of an inland remediation project of this magnitude from any place around the world, additionally of having the presence of UXO, harsh desert climate that can reach above 50°C during summer season, a soil with a high content of fines/clays and the potential high demand of water for any treatment intended.

In order to proceed with a new strategy some priorities were identified such as soil characterization, ground truth to better evaluate the magnitude of the soil to be remediated and its actual condition, UXO clearance, determination of available remediation companies to suit the needs of the project, definition of remediation targets, contracting strategies, potential costs of the remediation etc.

Based on the above priorities in order to efficiently remediate the contaminated soil, the Total Remediation Strategy (TRS) was developed in 2015 and approved by United Nations Compensation Commission as an environmental friendly approach to replace the initial strategy, which requires to construct a massive number of landfills. The TRS will ensure remediation through more sustainable environmental approaches, treating and Risk Based Approach (RBA) the majority of these materials and therefore reducing the number of landfills. The TRS comprises of

alternative remedial solutions and relies on treating ranges of Total Petroleum Hydrocarbon (TPH) contamination levels with appropriate remediation technique.

2. Material and Methods

2.1 Stakeholders

The projects under the Kuwait Environmental Remediation Program (KERP) are executed by different entities of the Government of the State of Kuwait, referred to as Stakeholders. Stakeholders includes Kuwait National Focal Point (KNFP), Kuwait Environment Public Authority (KEPA), Independent Reviewers (UN IR), Kuwait Ministry of Defense (KMOD), and Ministry of Electricity & Water (MEW) [2, 3].

2.2 Background

The Government of Kuwait was awarded, by the United Nations Compensation Commission (UNCC) [4] approximately US\$ 3 billion for environmental damages resulting from the Gulf War. Decision 258 of the UNCC Governing Council (S/AC.26/Dec.258 (2005)), which establishes the Follow up Program for Environmental Claims Awards, requires that project work plans be prepared as part of the initial planning for the execution of projects. Under Decision 269 (S/AC.26/Dec.269 (2011)), the preparation of "Reasonable Project Plans and Related Budgets" is listed as one of the criteria for early fulfilment of the mandate of the Governing Council over the Follow up Program under decision 258. These plans, which are commonly referred to as Project Plans, form the basis on which the Stakeholders execute the projects.

In 2003 the International Consortium of Consultants CIC produced a comprehensive report which assessed the extend of the contamination and its characteristics, volumes and the best potential practices or technologies applicable to remediate the contaminated soil. A large amount of chemical and physical test were carried out to the soil contaminated

at that time and a series of specialized bench test were performed to identify technologies capable of remediating the soil and their potential costs.

At the time of the CIC evaluation on the existing technologies, the most effective technology in terms of decontamination was thermal desorption, which further was dismissed due that fact that it eliminates any remnant bios to support further ecological natural recovery. Therefore, other technologies such as soil washing, chemical extraction and different types of bioremediation and landfilling were considered the best remediation options for the KERP programme way forward. The Awards to the KOC oil fields were consistent in the following:

2.2.1 Wet Oil Lakes Features

General description of the contaminated features are as follows, Crude oil flow from damaged oil wells and pipelines accumulated in shallow topographical depressions and drainage channels resulting in wet oil lakes on a volume of approximately 6 Million M³. The wet oil lakes largely comprise (Fig. 1):

- Sludge (which may have a thin bituminous crust) with high sediment loading (known as Layer 1), which in turn overlies;
- Visually stained sand with varying concentrations of oil contamination (Layer 2), overlying;
- Visually non-contaminated sands (Layer 3).

2.2.2 Dry Oil Lakes Features

The dry oil lakes are generally found in very shallow depressions and flat areas, frequently forming fringe areas around wet oil lakes. Dry oil lakes cover a much larger surface area than wet oil lakes. The dry oil lakes comprise (Fig. 2):

- A variable thickness, black, moderately hard to hard, tar-like dry surface layer (Layer 1), overlying;
- Visually stained sand with varying concentrations of oil contamination (Layer 2), overlying;
- Visually non-contaminated sands (Layer 3).



Fig. 1 Wet oil lakes.



Fig. 2 Dry oil lakes.

2.2.3 Tarcrete Features

Tarcrete is the most widely dispersed form of oil contamination. This is a function of its airborne

formation from crude oil ejected from damaged oil wells, whether ignited or not. Tarcrete forms a very thin hard crust typically beyond the extent of wet and

dry oil lakes and is a distinct material type. The crust varies in thickness and composition and can form either a continuous surface covering or a broken granular like bed. Tarcrete is characterized by an absence of oil-contaminated sand beneath the crust.

2.2.4 Oil Contaminated Piles Features

Oil-contaminated piles are man-made mounds of soil that are contaminated with crude oil. These are located where earth-moving equipment was used to consolidate oil-contaminated soil and/or liquid oil. These piles were made in an effort to stop the spread of oil flows caused by the destruction of oil wells, or

to clear areas of oil contamination as necessary to facilitate fire-fighting or subsequent KOC field operations.

2.2.5 Wellhead Pits Features

Wellhead pits are man-made excavated pits. The pits were constructed approximately 100 m-150 mm from previous oil wellheads and were created to either store sea water used to extinguish wellhead fires, or as a containment and storage area of released crude oil and associated contaminated soils, from vandalized or destroyed wellheads immediately following the Gulf war period.



Fig. 3 Tarcrete features.



Fig. 4 Oil Contaminated Piles Features.



Fig. 5 Wellheads Pits.

3. Total Remediation Solution Approach

3.1 Risk-Based Approach

The objective of risk-based remediation is to reduce the risk of oil contamination impacting human health, ecological receptors and/or groundwater. The risk-based approach relies on up to date chemical data, an understanding of soil type and receptor groups, model input parameters and a good understanding of

the mechanisms that form the conceptual site model (CSM). The risk-based approach will take into consideration the availability of contaminants to any identified receptors. Where areas impacted with oil contamination either show reduced concentrations through weathering and natural attenuation, or historically have low levels of harmful contaminants, then detailed quantitative risk assessment may identify areas that require limited or no remedial activity.

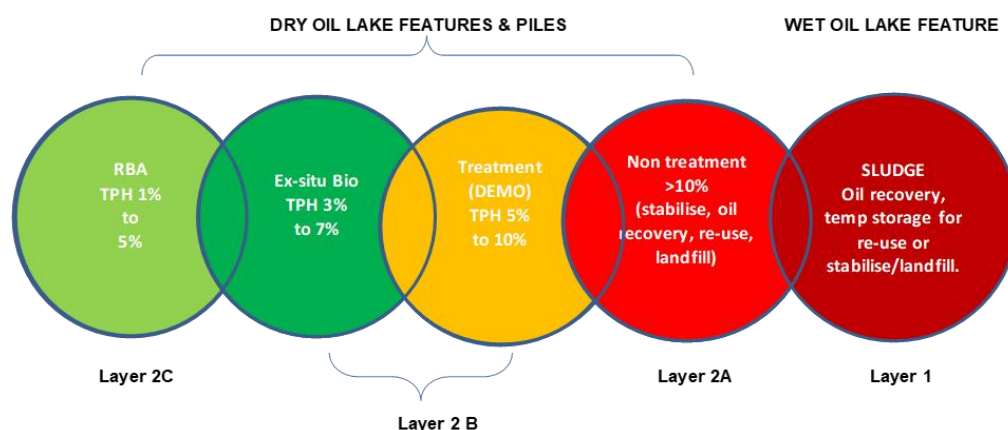


Fig. 6 Total remediation solution.

The RBA approach is a well-proven methodology in US, Europe and the UK where established legislation to support this approach is well understood and well proven. The approach relies on a detailed understanding of toxicology and pollutant linkages. An outline of the approach and an example of the regulatory guidance documents and framework that are used in the UK were presented to KEPA and KNFP in April 2014. The legal systems in these countries of origin, such as the UK, require this to be the adopted approach. For remediation compliance, regulatory agreement is required and therefore undertaking risk assessments to determine cut off levels for materials that require remediation. This approach presented to KEPA was well received and requires early demonstration on how it can be applied in Kuwait for the existing contaminated source features. Based on the planned strategy Tarcrete feature is likely to be eliminated from any future remediation works since the toxicity and risk to

human, ecology, and environment is negligible. Tarcrete currently is a thin crust and loose layer. It is dry and fragile that has low TPH value of 1-2% and accordingly has no harm to environment if left with no further treatment. Vegetation covers of native plants and shrubs are already revive in areas covered with Tarcrete.

3.2 Enhanced Ex-Situ Bioremediation

Bioremediation is an established treatment technology for remediation of crude oil contaminated soil as recommended within the UNCC Biannual Report 9 (BiAR9) as part of the existing remediation strategy. It is proposed the bioremediation will be included in several contracts to the treatment technologies as it treats a large quantity of material at low cost but with lower TPH concentrations. The enhanced method proposed is an ex-situ technique that offers optimum moisture retention and temperature control, greater control of nutrient input to ensure

optimum efficiency. It is also proposed to pre-treat all soils by running through a screening plant.

Bioremediation will handle 3.3 million m³ of contaminated soil mostly of dry oil lakes and oil contaminated piles in North Kuwait, which compose 80% of the total volume. Same percentage is applicable in bio treat contaminated soils in South Kuwait, which will cover dry oil lakes, underneath layer 2 of wet oil lakes and contaminated piles that have TPH value of approximate 5%. Bioremediation will contribute in treating a total soil spread over 15 million square meters.

3.3 Remediation Treatment Technologies

The goal of implementing Remediation Technologies as part of KERPS's Project is to identify alternative technologies to replace containment in engineered landfills. Available evidence (e.g., literature references, KOC SEED projects, results of the Invitation for Proposal) clearly demonstrate that it is not economically viable to treat the total volume of oil-contaminated materials with engineered technologies. It is considered given the existing timeframes the most material that will be treated using this element will be approximately 20 to 25% of the total volume available in North and South Kuwait. Technologies can include ex-situ soil washing systems, chemical oxidation systems, mechanical segregation and solvent extraction systems; and treatment Co-Processing or multiple treatment systems.

3.4 Options for Addressing Oil Sludge

As identified, remediation of oil sludge from the wet oil lakes is an essential element of KERP program. It represents the highest risk in terms of meeting program because of difficulties anticipated for UXO clearance. Sludge provides the option of assessing the market place for beneficial re-use material (such as fuel for cement kilns or construction industry as an example).

A market research study will be performed to evaluate the potential economic viability for a number of options. This includes (but is not limited to) the following: potential oil recovery processes; consider as feedstock for asphalt production, cement and brick manufacturing, and road construction.

Layer 1 of wet oil lakes category of 1 to 4 will be utilized for sludge reuse. It shall be moved to a temporary storage facility within the landfill footprint and stored until an economically viable market is recognized for re-use.

If it is determined there is no off-site disposal route as a fuel source or other reuse option then onsite disposal options may be considered. These may include stabilization or encapsulation.

3.5 Contaminant in Engineered Landfills

Disposal of crude oil contaminated soils through containment in engineered landfills was specified in UNCC decision documents and the estimated costs associated for this remedial approach formed the primary basis of the claim awards to the State of Kuwait. Modifications to Claim 5000454 Paragraphs 58 to 103 dated December 2004; refers to:

Appropriate remediation programme should be one that protects human health, assists in the restoration of ecological functions and is also cost-effective. Such a programme should involve excavation and off-site disposal at landfill for the most contaminated materials from oil lakes..., followed by bioremediation of underlying less contaminated soils.

However, TRS with bioremediation and remediation technologies were intended to eliminate unnecessary use of landfill disposal, and to only dispose of materials that are un-viable economically through remediation treatment options.

4. The Progress

4.1 Wet Oil Lakes in North Kuwait

One of the most critical environmental risks were the wet oil lakes in NK, about 350,000 m³ seating on

top to the underground fresh water aquifers in Um Al Aish and Raudhatain. These wet oil lakes were excavated and removed from their original location and transported to an engineered landfill as first priority for the KERP programme in NK.

4.2 Landfill Projects

North Kuwait landfill's Contract was to construct one Engineered Landfill facility for permanent containment of 1,700,000 m³ of waste. The Project occurred in two phases, Portion I "Construction of Engineered Landfill Cells" and Portion II, "Capping". The landfill was filled by the Excavation & Transportation Contractor between these two phases of work. Landfill was capped completely in 28 December 2018.

South Kuwait Landfill's Contract was to construct one Landfill facility for permanent containment of approximately 580,000 m³ of waste. The Project occurred in two phases, Portion I "Construction of Engineered Landfill Cells" and Portion II, "Capping". The landfill was filled by the E&T Contractor between these two phases of work.

4.3 Excavation and Transportation Projects

North Kuwait and South Kuwait Excavation and Transportation Projects included site establishment activities, unexploded ordnance (UXO) survey and clearance, site soil characterization, testing and trials for mixing and filling activities, development of excavation and material management plan.

Source features primarily include Oil Lakes, Oil Contaminated Piles and Wellhead pits located in Umm Al-Aish and Raudhatain, and coastal trench & coastal oil deposits. During this Project all features had been mixed, excavated and transported to the landfill.

4.4 UXO Phase-I Project

UXO Program Phase-I includes ground survey and clearance for remediation areas of North Kuwait to its

totality. This project consists of primarily of DOLs and OCPs in North Kuwait and DOLs, OCPs, and WOLs in South Kuwait.

5. The Way Forward

5.1 Optimization Plan 2017

KERP optimization plan aims of more remediated land in next set of projects, release more areas by independent UXO Projects and gather more data for remediation projects. Accordingly a group of enabling and specialized but independent projects were planned to be executed in both North and south Kuwait separately; as follows: S4C, UXO Phase I, II, Pile UXO screening, Sludge Management, Minor Remediation I, followed by mega Remediation II and III. After several optimization sessions and workshops among PMC and KOC teams it was concluded that merging S4C, UXO, and Remediation activities into one Project will maximize coordination among various disciplines, reduce duration of the Project cycle, and reduce the risk on Company.

5.2 Bioremediation SEK I

This Tender has been prepared to address soil excavation, bio treatment, and backfill for approximately 300,000 m³ of contaminated soil from SEK using the chemical and physical data collected during the Limited Site Soil Characterization (LSSC). The overlying Layer 1 material and higher contaminated soil above 7 percent TPH will be excavated and placed into a temporary holding area. The underlying soil with TPH concentrations less than 7 percent will be the focus of the ex-situ bioremediation soil treatment. Based on the LSSC data, it is assumed that most of the soil will have concentrations less than 4 percent, with a significant fraction of higher carbon chained TPH (i.e., above EC 40). UXO clearance for the soil was performed under the SEK E&T and the UXO Phase 1 Projects.

5.3 Remediation North Kuwait

The works are for remediating the remaining existing and accessible KERP contaminated features within Raudhatain and Sabriyah oilfields. The scope of works will include: Identify and quantify as per site soil characterization the volumes of soil for Total Petroleum Hydrocarbon (TPH). Excavation of approximately $\pm 4,000,000 \text{ m}^3$ of contaminated material. Carry out all necessary pre-treatment processes as necessary based on remediation method. Also; Bio-remediate 95% of the soil contaminated with TPH of 0.5 % to $\leq 5\%$. The Project will cover 12 million m^2 of DOL's and OCP's.

5.4 Remediation SK-II

This project will consist of one Tender with three awards for discrete areas of the oilfield, nominally Northern Burgan, Central Burgan and South Burgan to treat the largest amount of contaminated soil. The works are for remediating the contaminated features within the Greater Burgan oilfield. A major element of the project will be UXO clearance. UXO Phase-1 will be used as a UXO clearance "buffer" to advance early works to be incorporated into the Remediation SK-II and Remediation SK-III works. Remediation shall comprise bioremediation, treatment technologies, re-use and landfill of wet oil lakes, oil contaminated piles and dry oil lake broadly. Landfills shall be reserved for not economically treatable materials such as residual materials from treatment processes and for any materials (e.g., Layer 1) that are technically, legally, or economically unviable for re-use. Market research shall be required, either as part of the Contract, or earlier, to determine the economic viability for re-use of wet oil lake Layer 1 materials (all typologies).

5.5 Final Remediation SK-III

The remaining contamination requiring remediation within the Greater Burgan oilfield shall be addressed under Remediation SK-III once the full extent of contamination has been more clearly understood and application of the Risk Based Approach in line with the TRS. The approach is currently expected to generally follow the approaches set for Remediation NK and Remediation SK-II. And the volumes to be treated are in the magnitude of 9million m^3 .

6. Conclusion

Kuwait environmental Remediation Program undertake a massive effort to remediate over twenty-six Million m^3 of highly contaminated soil, which has been exposed for more than 27 years to a harsh weather. KOC represented by KERP plan to reclaim Kuwaiti lands to its mother nature through KERP Optimization Plan.

Moreover, the program through its strategy will ensure that the remediation process will follow sustainable approaches (Economically, Environmentally and socially).

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