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Environmental and Economical Oil and Groundwater Recovery and Treatment Options for hydrocarbon contaminated Sites

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Abstract. This paper describes a decision framework for selecting appropriate remediation technologies at hydrocarbon contaminated sites in a controlled method. Assessment modules include site characterization and product recovery. The decision framework provides a systematic process to formulate solutions to complex problems and documents the foundation for selecting remediation technology/systems designed to achieve cessation at hydrocarbon contaminated sites.
The environmental safety of soil has become significant in Kuwait with the enhancement of industrialization and urbanization. In this paper, on the basis of investigating the status of soil contaminated in Kuwait, the remediation technologies of soil contaminated by hydrocarbon and heavy metals, including physical remediation, chemical remediation and biological remediation were focused.
The summary for each technology includes a broad description of the technology, its implementation, applicability based on contaminants and site characteristics, general limitations, costs, and status of the technology's application. Information in this paper is intended to give project managers a comprehensive understanding of the technology and guidance on the design and operation of these technologies that will allow for further consideration of its applicability.

Keywords: Hydrocarbon contaminated sites, remediation technologies, contaminated soil, Remediation Decision Framework.

1. Introduction

There are many applicable technologies for treating sites contaminated with petroleum hydrocarbon. The effectiveness of these technologies, however, is dependent on contaminant and site characteristics, regulatory requirements, and cost limitations. This guideline describes the process that is used to manage (e.g. identify, assess, remediate) contaminated or potentially contaminated sites

2. Technology Descriptions

To understand the decision framework for technology selection, it is important to understand the general principles of applicable technologies for the remediation of petroleum hydrocarbon-contaminated sites. Some information about technologies for treating petroleum-hydrocarbon contamination was compiled by Environmental Solutions, Inc. (March 1990) for the Western States Petroleum Institute (WSPI). The WSPI manual provides technology descriptions and an overview of the technology screening process. EPA has also compiled technology descriptions for processes that treat contaminated soils and sludges (USEPA, 1988). Emerging and developing technologies being investigated in EPA's Superfund Innovative Treatment Evaluation Program (SITE) have also been described (USEPA, 1991).

3. The Remediation Decision Framework

To select appropriate technologies the following information is needed:

1- Applicability of technology to site contaminants

2- Variations in technology design

3- Site characteristics

4- Regulatory acceptance of technology and required permits

5- Technology availability

6- Treatment time objectives

7- Project life-cycle costs

The treatment technologies presented include common practices as well as innovative alternatives for treating contaminated soil and source zones in situ and Ex Situ. The paper does not address technologies in the experimental phase [1].

4. In Situ Treatment Technologies

The in situ technologies are categorized into three major groups based on the primary mechanism by which treatment is achieved:

- Physical/Chemical Treatment Technologies
- Biological Treatment Technologies
- Thermal Treatment Technologies

Physical/chemical treatment includes soil vapor extraction, solidification/stabilization, soil flushing, chemical oxidation, and electro kinetic separation. Biological treatment uses microorganisms or vegetation to degrade, remove, or immobilize contamination in soil. Biological technologies include bioventing, phytoremediation, and monitored natural attenuation. Electrical resistivity heating, steam injection and extraction, conductive heating, radio-frequency heating, and verification are technologies summarized under thermal treatment [2].

5. Ex Situ Treatment Technologies

Ex situ technologies are remediation options where the affected medium (soil, water) is removed from its original location and cleaned on-site or off-site. Examples: bioremediation or soil washing.

Ex situ (as well as in situ) remediation options can be grouped into categories based on their treatment mechanism: physical, chemical, electrical, thermal and biological. In this digest, physical, chemical and electrical mechanisms have been abridged into one group, called physico-chemical. Due to the complex nature of many polluted soils and the fact that pollution, in many situations, is due to the presence of a “cocktail” of different types of contaminants, it is frequently necessary to apply more than one remediation technique (treatment train) to reduce the concentrations of pollutants to acceptable levels Table 1 [3].

Table 1: Alternative Petroleum-Contaminated Soil Treatment Technologes

General Category	**Type of Process**	**Technology applied in-Situ**	**Technology Applied Ex-Situ**
Treatment	*Biological*	• Passive biodegradation • Bioventing • In-Situ Biodegradation	• Biopiles • Land treatment or landfarming • Slurry biodegradation
	Physical	• Soil Venting - Conventional - Hot air or steam stripping • Soil flushing	• Soil washing • Coal tar agglomeration
	Chemical	• Chemical Oxidation/reduction	• Chemical Oxidation/reduction • Solvent extraction
	Thermal	• Radio frequency (RF) heating • Vitrification	• Thermal desorption by: -Low and high temperature. -Thermal strippers - Hot-mix asphalt plants • Vitrifecation
Containment	*Other*	• Solidification/stabilization • Capping	• Solidification/stabilization • Microcantaminated by cold-mix asphalt • Capping or re-use • Land disposal or Land filling

6. Technology Selection Process

The Contaminated Site Management Process consists of five steps from the time that contamination is discovered to final site remediation and closure [4]. The following flow chart defines the steps in the overall management process Fig.1.

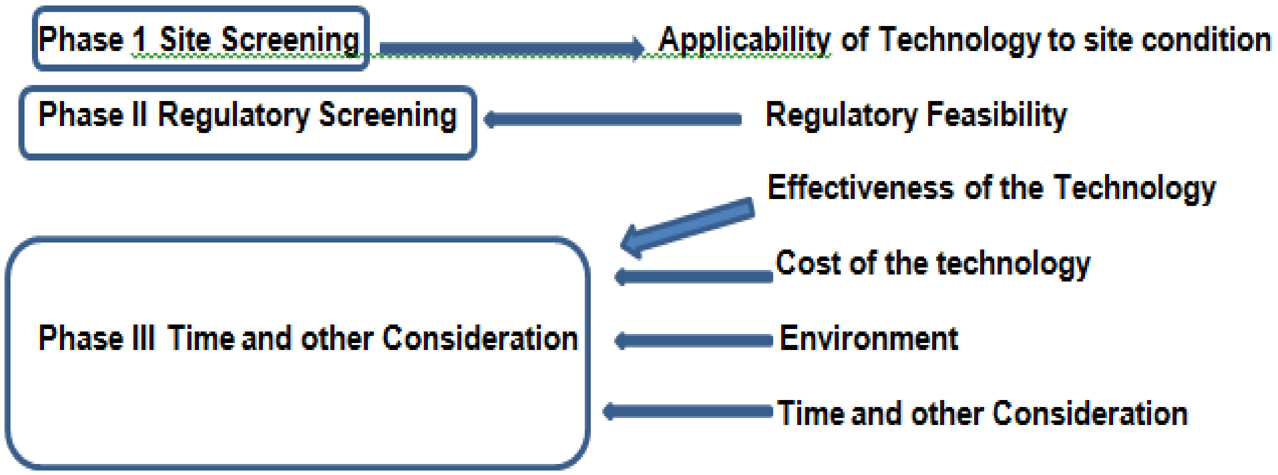

Fig. 1

7. Groundwater Recovery and Treatment

Groundwater treatment consists of (1) groundwater withdrawal from the subsurface and (2) above-ground treatment of recovered groundwater. Additionally, groundwater containment technologies may be used to gain hydraulic control of contaminant plumes. Groundwater pumping is primarily used as a containment strategy. It has been shown to enhance remediation but is effective as a sole remediation technique for only very soluble contaminants such as MTBE.

Groundwater treatment technologies for recovered groundwater containing petroleum-hydrocarbon contamination generally consist of both separation technologies such as (1) liquid-phase carbon adsorption and (2) air stripping, or destructive technologies such as (3) advanced oxidation and (4) bioreactors. Separation technologies are generally the most cost-effective approach for treating recovered groundwater containing petroleum-hydrocarbon contamination, although off-gas treatment requirements for air strippers and carbon disposal costs may add significantly to total treatment costs. Advanced oxidation and bioreactors should be considered for treating recovered groundwater that is contaminated with organics that are not amenable to air stripping and carbon-adsorption treatment. Advanced oxidation is effective for treating aromatic compounds such as BTEX as well as water-soluble contaminants (such as phenols) that cannot be removed efficiently by air stripping or activated carbon. Bioreactors can also effectively treat BTEX and soluble compounds such as phenol, alcohols, and ketones.

7.1. Processes that Affect the Impact of Oil when It Mix with Water

Oil is a complicated mixture of many components, and when it mix with water the water surface will largely be effected, and this will depends on the initial properties of the oil and composition as well as on specific local environmental conditions. Spreading, evaporation, dispersion, and emulsification can rapidly alter oil properties within several hours, leading to formation of water in oil emulsion. The same type of oil released under different environmental conditions disperses in dramatically different patterns due to the influence of air and sea temperature, wind speed, and weather. Oil dispersal and deterioration can have significant ramifications.

7.1.1. Weathering

Following an oil spill or any other event that releases crude oil or crude oil products into the marine environment, weathering processes begin immediately to transform the materials into substances with physical and chemical characteristics that differ from the original source material [5].

7.1.2. Emulsification

Emulsification is the process of formation of various states of water in oil, often called “chocolate mousse” or “mousse” among oil spill workers [6].

7.1.3. Dissolution

Dissolution is the chemical stabilization of oil components in water. Dissolution accounts for only a small portion of oil loss, but it is still considered an important behavior parameter because the soluble components of oil, particularly the smaller aromatic compounds, are more toxic to aquatic species than the aliphatic components. Modeling interest in dissolution is directed at predicting the concentrations of dissolved components in the water column. Most models in existence do not separate the dissolution component. The entrainment model is sometimes used but fails to distinguish between dispersion and dissolution.

7.1.4. Oxidation

Oxidation occurs when oil contacts the water and oxygen combines with the oil hydrocarbons to produce water-soluble compounds. This process affects oil slicks mostly around their edges. Thick slicks may only partially oxidize, forming tar balls. These dense, sticky black spheres may linger in the environment, washing up on shorelines long after a spill.

7.1.5. Evaporation

Evaporation occurs when the lighter or more volatile substances within the oil mixture become vapors and leave the surface of the water. This process leaves behind the heavier components of the oil, which may undergo further weathering or may sink to the bottom of the ocean floor. Spills of lighter refined products, such as kerosene and gasoline, contain a high proportion of flammable components known as light ends. These may evaporate within a few hours, causing minimal harm to the aquatic environment. Heavier oils, vegetable oils, and animal fats leave a thicker, more viscous residue. These types of oils are less likely to evaporate.

Environmental factors that affect the rate of evaporation are:

- Area of slick exposed, which changes rapidly
- Wind speed and water surface roughness
- Air temperature and solar radiation
- Formation of emulsions, which dramatically slows evaporation

All these factors must be carefully considered when developing an oil spill response plan [7].

7.2. Water Reclamation and Management

Full understanding of the impact of petroleum loadings into the water requires an accurate assessment of the magnitude, spatial extent, and duration of exposure. Because of the incredible diversity of physical environments within the lagoons each case have deferent assumptions and conclusions for example wind directional changes, variances in crude oil concentrations in the lagoon, oil layer thickness, evaporation etc all have to be taken into account when trying to establish a recovery rate. That’s way each lagoon has various recovery coordination. it is not possible to derive simple generic relationships between petroleum mass loadings and ambient concentrations that can be applied universally. The “fate” (where it goes) and “persistence” (how long it remains in the system) of petroleum in water are controlled by processes that vary considerably in space and time.

8. Contaminated Sites Management Process

The Contaminated Site Management Process consists of five steps from the time that contamination is discovered to final site remediation and closure. The following steps defines the overall management process [4].

Step 1: Initial Notification

Step 2: Initial Site Assessment

Step 3: Site Information Assessment

Step 4: Prepare and submit Remedial Action Plan

Step 5: Remedial Action Plan Implementation

Step 6: Closure Report and issuing letter advising that no further remedial action is required

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