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Review

A comprehensive guide of remediation technologies for oil contaminated soil — Present works and future directions

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ABSTRACT

Oil spills result in negative impacts on the environment, economy and society. Due to tidal and waves actions, the oil spillage affects the shorelines by adhering to the soil, making it difficult for immediate cleaning of the soil. As shoreline clean-up is the most costly component of a response operation, there is a need for effective oil remediation technologies. This paper provides a review on the remediation technologies for soil contaminated with various types of oil, including diesel, crude oil, petroleum, lubricating oil, bitumen and bunker oil. The methods discussed include solvent extraction, bioremediation, phytoremediation, chemical oxidation, electrokinetic remediation, thermal technologies, ultrasonication, flotation and integrated remediation technologies. Each of these technologies was discussed, and associated with their advantages, disadvantages, advancements and future work in detail. Nonetheless, it is important to note that no single remediation technology is considered the best solution for the remediation of oil contaminated soil.

Capsule: This review provides a comprehensive literature on the various remediation technologies studied in the removal of different oil types from soil.

Contents

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1. Introduction

In the past, marine oil spills have caused devastating impacts on both shorelines and seas due to the hazardous property of the oil. In 1978, the large oil spill due to the Amoco Cadiz in France released over 223,000 tonnes of light crude oil and 4000 tonnes of bunker oil, contaminating a total shoreline length of 320 km up to a depth of 20 inches (Conan et al., 1982; Haensly et al., 1982). Failure to remove oil from the shoreline resulted in a long term contamination, with layers of oil still remained buried in the beach site up to 8 years after the oil spill incident (Page et al., 1988). Similarly the *Exxon Valdez* oil spill in 1989 which spilled 11 million gallons of crude oil into the sea drifted and damaged up to 1300 miles of shoreline (Paine et al., 1996). Despite the efforts in clean-up, only 10% of the oil was recovered (Bragg et al., 1994). A study by National Oceanic and Atmospheric Administration (NOAA) showed that more than 87 m^3 of oil still remains in the Alaska's sandy soil in the contaminated beaches shoreline as of 2010, breaking down at a rate estimated at 4% per year (Register, 2010). Table 1 summarizes the top 10 largest oil spills and the corresponding clean-up costs, ranging from controversial oil spills to accidental oil spills in history.

The toxicity of oil spills on contaminated soil is of a great concern especially on the environment, and this issue had been highlighted by several groups of researchers (El-Sheshtawy et al., 2014; Gao et al., 2015; Hentati et al., 2013; Kanarbik et al., 2014; Ma et al., 2014a; Tang et al., 2011). Tang et al. (2011) investigated on the toxic effects of petroleum soil contamination of up to 10.57% on the earthworm, bacteria and plant. The death rate of earthworms was at 90% after 7 days at oil content of 2%, while no earthworms survived in the soil contaminated with oil content of 3% and more. Likewise, inhibition rate of bacteria is nearly 100% at petroleum content of 1%. In terms of plant germination at oil content of 3%, the germination inhibition rate of maize and wheat is 51.3% and 48.4% respectively. The root growth also showed similar trend whereby higher concentrations of oil inhibit the growth of roots (Tang et al., 2011). Similarly, increase in oil concentration from 31 mg/kg to 1000 mg/kg was found to vastly decrease the survival rate of earthworms from 80% to 33% after 14 days (Hentati et al., 2013). In addition, a recent study by Ramadass et al. (2015) also showed that used motor oil concentrations of greater than 3.88 g/kg soil caused complete mortality of earth worms. Clearly, it could be seen that the oil spillage on soil greatly impacts the surrounding environments, which highlights the urgent need for effective removal of oil contaminant from soil.

At present, most clean-up efforts for oil spill on soil and shoreline require mechanical and labour intensive methods as they may be a quick and simple solution to remove oil contaminants (Broman et al., 1983). However, there are many disadvantages associated to these methods. For instance, the usage of high pressure washing to displace oil may destroy the microbial populations, while the chemical sorbents and