



## Evaluation of soil property–dependent interactions of surfactant and diesel in a soil–water system

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### ABSTRACT

Experimental studies were conducted to remove hydrophobic organic compounds (HOCs) from diesel fuel-contaminated soil. Interactions between non-ionic surfactants and diesel fuel were investigated to understand the partitioning effect in heterogeneous soil–water–surfactant systems. The effective critical micellar concentration (CMC<sub>eff</sub>) was identified from surfactant adsorption, which led to the maximum partitioning of HOCs in the system. This partitioning was attributed to the surfactant (i) lowering the interfacial tension between HOC and soil, (ii) solubilizing HOCs, and (iii) mobilizing HOCs from a solid phase to a pseudo-aqueous phase. The strong adsorption capacity of clay in the soil led to an increase of CMC<sub>eff</sub> from 20 to 2,500 mg/L of Tween 80. The data for surfactant adsorption and desorption on the soil followed Freundlich's isotherm and showed irreversible adsorption for surfactant, especially in the presence of clay. The diesel migration from soils to the aqueous phase of surfactant was observed beyond its derived CMC value. The maximum removal efficiency of HOCs could be reached at CMC<sub>eff</sub> of surfactant due to the higher solubility and competitive adsorption in the presence of clay. Understanding of the soil-surfactant-diesel behavior helped in the effective field implementation of surfactant-enhanced soil flushing for the remediation of oil-contaminated soil.

### Introduction

Anthropogenic activities generate petroleum hydrocarbon contamination in soil, also referred to as hydrophobic organic compounds (HOCs). Widespread HOCs contaminated soil affected public health and environmental quality [1,2]. HOCs and alkanes present in diesel fuels are potentially carcinogenic, cytotoxic, and mutagenic to organisms that can alter the microfloral composition of the soil [3,4]. Hydrocarbon-based pollutants have a higher distribution coefficient for oil and less water solubility, resulting in partitioning in a soil matrix and forming non-aqueous phase liquid (NAPL) aquifers [5]. Conventional oil-contaminated soil remediation processes, such as incineration,

bioremediation, and chemical treatment, suffer from either partial removal efficiency or tailing and rebound effects, which are frequently observed to threaten the soil systems [6]. Recent research has focused on detaching oil contaminants from soil surfaces while elucidating the detailed interaction mechanisms of contaminants and clay surfaces [7].

Surfactant applications in aquifers may lead to the downward movement of dense NAPLs, generation of secondary contamination, loss of surfactants during the adsorption of clay particles, precipitation and partitioning, and aquifer heterogeneity, which reduces surfactant-enhanced aquifer remediation (SEAR) efficiency in NAPL removal [8]. Non-ionic surfactants have demonstrated a strong ability to solubilize and remove HOCs from contaminated soil with relatively low chances of

**Abbreviations:** BET, Brunauer-Emmett-Teller; CMC, Critical micellar concentration; CMC<sub>eff</sub>, Effective CMC; FT-IR, Fourier-transform infrared spectroscopy; HI, Hysteresis index; HOCs, Hydrophobic organic compounds; NAPL, Non-aqueous phase liquid; PSA, Particle-size analyzer;  $r_{sw}$ , Solid-to-water mass ratio; SEAR, Surfactant-enhanced aquifer remediation; TGA, Thermogravimetric analysis; TW80, Tween 80.

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