



The use of nanotechnology for oil recovery at low temperatures

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ABSTRACT

The potential opening of petroleum-related activities in the Arctic due to climate change has increased the risk of oil discharges and spills, which was already significant due to drilling and shipping. Oil spill response in this region is challenging due to harsh weather conditions and the current limitations of clean-up techniques. Therefore, a safe, rapid, and effective approach is needed for an efficient response to oil spills in Arctic, and other cold, regions. Quantitative oil removal from seawater using polyvinylpyrrolidone (PVP)-coated iron oxide nanoparticles (PVP-IONPs) under environmentally relevant conditions had been previously demonstrated. However, this method has only been tested at room temperature. This paper examined the efficacy of oil sorption by PVP-IONPs in low temperatures comparable to those of polar waters, in both synthetic and natural seawaters. Physico-chemical characteristics of the PVP-IONPs were consistent with previous batches. Oil removal results clearly indicated that removal of aliphatic and aromatic components was approximately 100% in synthetic marine waters with and without natural organic macromolecules (NOM), and there was no significant or systematic effect of temperature. Longer chain aliphatics were slightly less well removed (50–100% removal for C22–C26) as seen before, but unaffected by temperature. Interestingly, no change in removal effectiveness was observed even at -3°C (vigorously mixed saline waters). The finding that nano-enabled removal was equally effective at all tested temperatures, suggests that this technology may be suitable for deployment in low temperature operational environments where the applicability of conventional methods is limited.

1. Introduction

Oil drilling and transport, along with other commercial transport which uses large volumes of oil and diesel, are on-going in Arctic regions, and other cold regions. These activities increase the risk of oil spills (Toxværd et al., 2018). Such spills in open Arctic waters have caused severe impacts due to the relatively pristine environment, their distance from suitable infrastructure and the logistics of transporting cleanup crews, equipment, and waste, and the likelihood of rapidly changing weather conditions. The oil spill from the *Exxon Valdez*, in 1989, is a key example of the risk associated with increased oil transportation in the Arctic (Bragg et al., 1994; Neff et al., 1995). It was the catalyst for the US Oil Protection Act (1990), which placed requirements on oil clean-up in the US. The spill caused lasting damage to the habitats of aquatic animals and the broader environment and created long-term health problems for local people (Harvey et al., 1990; Incardona et al.,

2013; Short, 2003; Short et al., 2004.). Previous studies showed that the oil from *Exxon Valdez* spill has persisted for more than 20 years (Lindeberg et al., 2018; Short, 2017). Strong winds caused the oil to spread more than 12 miles from the source and contaminate nearby rivers, lakes, and the surrounding soil which posed a significant threat to the Arctic ecosystem (Kirdyanov et al., 2020). Due to the hazardous nature of crude oil spills to human health and the environment and limited improvements in technology since 1989, new methods for treatment are required. Similar issues face countries such as Canada and Norway.

Current oil clean-up methods used in open ocean Arctic system are based on in-situ and ex-situ techniques (Chaudhary and Kim, 2019; Wilkinson and Lead, 2007). In-situ techniques such as chemical dispersant use, on-site bioremediation, and in-situ burning involve processes which treat the oil spill without physical removal. Ex-situ techniques include booms and skimmers, which remove oily water

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