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Investigating the effectiveness of economically sustainable carrier material complexes for marine oil remediation

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HIGHLIGHTS

- Three novel bioaugmented and biostimulated carrier materials were assessed.
- Mussel shells and mussel shell agar complexes were determined to be the most effective materials.
- Approximately 55–49% of the recalcitrant weathered oil was degraded.
- Carrier materials were not intrusive to native seawater microbial community.

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ABSTRACT

The application of bioremediation to marine oil spills is limited due to dilution of either nutrients or hydrocarbonoclastic organisms. This study investigated the effectiveness of three unique natural carrier materials (mussel shells, coir peat and mussel shell/agar complex) which allowed nutrients, hydrocarbonoclastic organisms and oil to be in contact, facilitating remediation. TPH analysis after 30 d showed that mussel shells exhibited the greatest capacity to degrade oil with a 55% reduction (123.3 mg l^{-1} from 276 mg l^{-1}) followed by mussel shell/agar complex (49%) and coir peat (36%). Both the mussel shells and mussel shell/agar complex carriers were significantly different to the control ($P = 0.008$ and $P = 0.002$, respectively). DGGE based cluster analysis of the seawater microbial community showed groupings based on time rather than carriers. This study demonstrated that inexpensive, accessible waste materials used as carriers of hydrocarbonoclastic bacteria led to significant degradation of hydrocarbon contaminants in seawater.

1. Introduction

Oil pollution in the marine environment has long lasting ecological and anthropogenic effects. In 2010, the British Petroleum Deepwater Horizon spill in the Gulf of Mexico saw 26.5 million litres of oil released into the greater oceanic environment. This catastrophic spill served as a timely reminder that the current methodologies relating to the degradation and remediation of oil within the marine environment are limited. Conventional treatments of an oil contaminated area include the application of booms, skims and adsorbents. These typically only recover approximately 10–15% of the spilled oil (Thavasi et al., 2011). Alternatively, dispersants can be used. Dispersants are chemical formulations (containing surfactants, solvents and stabilising agents) that are designed to reduce the interfacial tension between oil and water. The function of dispersants is to move the oil into the water column, in the form of the smaller oil droplets, which in turn facilitates quicker natural biodegradation and dispersion (Dave and Ghaly, 2011). However, both chemical surfactants and dispersants have been shown to have both acute and chronic costs of use economically and environmentally, (Singer et al., 2001).

Bioremediation has yet to prove an effective counter measure to an open sea oil spill within the marine environment, although it has been proven to be an effective treatment in the remediation of oil washed up on the shore. Bioremediation can generally be defined as the application of biological systems for the cleanup of the environment (Boopathy, 2000; Makadia et al., 2011). This process may be enhanced through bio-augmentation (the addition of microbes) and bio-stimulation which sees the addition of nutrients (such as nitrogen and phosphate). It is also essential for microbes to have direct contact with the hydrocarbon substrate as microbial degradation of hydrocarbons occurs at the hydrocarbon/water interface (Rosenberg et al., 1992). Bioremediation in the marine environment has traditionally thought to be limited by the ability of microbes to access nutrients such as nitrogen and phosphorus (McKew et al., 2007). Low availability of such nutrients has been well documented as major limiting factors in the remediation

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