

Biostimulation in Marine Oil Spills: Supplementation of Limiting Nutrients to Hydrocarbon Degrading Bacteria

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Abstract

Spilled crude oil in a marine environment is extremely difficult to contain and clean. Conventional clean up methods, such as high pressure beach washing, manual cleaning, and chemical cleaners are labor-intensive and possibly disruptive to the ecosystem. Bioremediation, or the use of bacteria to metabolize pollutants, is a promising method of cleaning up crude oil spills in a marine environment. Oil-degrading bacteria exist in natural marine ecosystems, but nitrogen and phosphorus are often limiting nutrients. Biostimulation, or the addition of nutrients to speed growth of oil-degrading bacteria, is a method that has received much attention as an effective way to clean up oil spills on shorelines. Challenges such as nutrient formulation, delivery, heterogeneous shoreline conditions, and environmental concerns must be overcome before biostimulation can be an accepted method of dealing with marine crude oil spills.

Key Words

Bioremediation, biostimulation, crude oil, marine environment, hydrocarbons, bioaugmentation

Introduction

In March of 1989, the *Exxon Valdez* ran aground in Prince William Sound, Alaska, spewing 41 million liters of crude oil, contaminating 2,000 km of pristine Alaskan coastline, and spurring one of the most extensive oil clean-up efforts in history (Bragg et al., 1994). The spill was the largest oil spill in history in the United States. Commercial fishing, vital to the economy of the Prince William Sound area, was in danger of being completely wiped out by the spill, as were the habitats of up to ten million migratory birds and waterfowl, as well as sea otters, whales, porpoises, and sea lions (EPA, 2004). Oil-covered rocks and wildlife dominated the nightly news after the spill, with images of volunteers carefully swabbing oil from injured animals on a beach covered in a sticky black oil. When such powerful images are displayed, and indeed when such a large and delicate ecosystem is challenged, the public demands new and better ways of dealing with such ecological disasters.

After the hype over the newest genetically engineered “superbug” dies down, most scientists agree that nature has supplied the oceans with the diversity of bacterial life to degrade substances even as noxious as crude oil (Lee, 1999). Bioremediation, or the utilization of bacteria to degrade toxic substances like crude oil in nature, has been shown to be an effective degrader of most components of the oil. By biostimulation, or the addition of vital nutrients to the affected area in an attempt to increase the growth of oil-degrading bacteria, researchers have shown that natural degradation pathways can be utilized to break down crude oil in a marine shoreline environment.

This paper attempts to address several issues surrounding the role of biostimulation in oil spill cleanup efforts. First, an overview of marine oil removal strategies will be given, followed by an examination of the factors that affect the success or failure of biostimulation. Requirements for an effective nutrient source will then be discussed, followed by a review of nutrient sources tested in both laboratory experiments and field cleanup efforts. Finally, biostimulation guidelines, concerns and further research necessary for the successful and safe application of these technologies will be addressed.

Strategies for Oil Removal

Just one strategy will never be sufficient to clean up major marine oil spills. Crude oil is a complex mixture of hydrocarbons, ranging from tens to upwards of 60 carbons, arranged in straight-chains, branched chains, aromatic rings, and with a variety of substituent groups that vary in toxicity, electronegativity, and size. Some are volatile, some are not, and they vary in toxicity and ease of breakdown. When an oil slick reaches a beach, dispersion in the water column is no longer an option, and other ways must be found to remove it. Methods for beach cleanup include manual cleaning, that is, shovels and hoses on the beach, heavy machinery to scoop up contaminated soil and debris, spraying with high-pressure water, controlled burning, and the use of chemical cleaners and dispersants.

By-hand cleaning of beaches has shown to be important, but labor-intensive and sometimes wholly ineffective. When the oil tanker *Prestige* released her cargo off the coast of northwest Spain, the