OCS Study
MMS 98-0018

Effects and Management of Oil Spills in Marsh Ecosystems

A Review Produced from a Workshop Convened July 1996 at McNeese State University

MMS U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

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Bioremediation Research and Development for Marine Oil Spills

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DEFINITIONS

Biodegradation is a natural process in which microorganisms chemically alter and breakdown organic molecules into other substances, such as carbon dioxide, fatty acids, and water, in order to obtain energy and nutrients. Because microbes capable of degrading hydrocarbons are commonly found in nature, most untreated oil spills eventually are removed from the environment by microbial degradation and other processes.

Bioremediation is a treatment technology that utilizes biodegradation to reduce the concentration and/or toxicity of chemical substances such as petroleum products and other hydrocarbons. It seeks to accelerate natural biodegradation processes by applying specially chosen nutrients (nutrient addition), microbes (bioaugmentation) and/or oxidants to environments contaminated by, for example, spilled oil.

BACKGROUND

Bioremediation of marine oil spills is an idea that has been around since at least the early 1970s (Ahearn 1973, Miget 1973). For nearly twenty years, however, the lack of scientific credibility precluded its acceptance by the governmental response community. In 1989 and 1990, things began to change. Three nationally significant oil spills highlighted the promise and pitfalls of the method. Scientific studies of shorelines impacted by the Exxon Valdez incident indicated that nutrient addition enhanced oil biodegradation rates (Pritchard and Costa 1991). Attempts at bioremediation during the Megaborg tanker and Apex barge spills along the Texas Gulf Coast emphasized the lack of credible science and adequate response planning for the technique. The 1990 Oil Pollution Act (OPA) provided incentives for development of innovative response technology, including bioremediation.

During 1990, the Administrator of the Environmental Protection Agency (EPA) met with representatives of industry to establish goals for the safe development and use of biotechnology. To follow up on recommendations from that meeting, a government- industry Bioremediation Action Committee (BAC) was formed. The BAC Subcommittee on National Bioremediation Response developed the Interim Guidelines for Preparing Bioremediation Spill Response Plans (EPA 1991). Using the scientific criteria and the response decision-making recommendations contained in the Guidelines, several federal Regional Response Teams have now developed their own regional protocols for response.

The BAC's Treatability Protocol Development Subcommittee prepared tiered

protocols for assessing the efficacy and toxicity bioremediation products: gathering of existing information about a product (base tier and tier I); laboratory scale protocols for estimating product efficacy and toxicity (tier II); laboratory mesocosms to simulate field testing (tier III); and field scale testing (tier IV). The base tier and tiers I & II are in Subpart J of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR Part 300, as a requirement for testing products seeking eligibility for use by Federal On-Scene Coordinators. Further development and utilization of tiers III and IV are areas of needed research.

The use of bioremediation to treat waters of the U.S. contaminated by spilled oil must follow the approval process outlined in Subpart J of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR Part 300. It is important that R&D objectives include meeting the needs of that process; critical end users of research data are the response community managers, planners and decision makers and the natural resource trustees.

Federal Responsibility for Bioremediation Research and Development

Title VII of OPA 90 established an Interagency Coordinating Committee on Oil Pollution Research, with a charge to coordinate a comprehensive program of research, technology development, and demonstration among Federal agencies in cooperation with industry, universities, research institutions, State governments, and other countries. In 1992, the Committee convened the First International Oil Spill R&D Forum (Sheehan 1992a) to provide an opportunity for the international community to promote cooperation on oil spill research. During the same year, the committee published its Oil Pollution Research and Technology Plan (Sheehan 1992b), which among other things identified agency roles and responsibilities and established research priorities and goals. EPA was given lead responsibility for oil spill bioremediation technologies. Prioritized research projects are listed for bioremediation on pages 3.3-31 and 32 in the plan and are reflected in the Research Recommendations section of this report.

Since 1971, the EPA Administrator has been responsible for reviewing and approving proposals to deliberately spill oil in waters of the U.S. for the purposes of research and development. Recent heightened interest in bioremediation research to meet the needs of the response community has resulted in the granting of permitted oil spills.

Status of Bioremediation in Coastal Marine Oil Spills

Bioremediation currently occupies a credible place in the national oil spill response program, and is among the options now routinely considered by federal and state response managers and Regional Response Teams. Spills in open water environments are not considered candidates for bioremediation (EPA 1992); appropriate applications are in the coastal marine shorelines and wetlands.

The present consensus within the response community does not view bioremediation as an "emergency" procedure but as a long term cleanup process to be considered after mechanical removal has been precluded or completed. The time scale for the biodegradation

processes, even enhanced, is weeks to months, not hours to days (Owen 1991).

While contingency planning for bioremediation rapidly progressed once credible scientific underpinnings started becoming available, there remains a considerable amount of research and development necessary. No where is that more evident than in the need for cost effective monitoring protocols to serve two separate groups. Early in a pollution incident, response managers have an operational need for real time monitoring of the efficacy and safety of bioremedial applications. Later, the natural resource trustees may elect bioremediation as a means to reduce the duration of pollutant impact or for environmental restoration and will need protocols for monitoring those projects. The extent of monitoring that must be incorporated is largely specific to the incident and the needs of the data user. While EPA has developed a comprehensive monitoring guidance, there remains a critical need to establish cost feasible, "minimumly adequate" monitoring protocols for operational use that can be incorporated in response pre-planning documents.

Until recently, credible scientific underpinnings meant the results of the Exxon Valdez nutrient addition bioremediation study. Research (Venosa et al. 1992) has also demonstrated the efficacy of nutrient additions during a coastal shoreline field study. The study demonstrated that inorganic mineral nutrient additions significantly enhanced the natural, or intrinsic, rate of oil biodegradation. An on-going field research effort at Parker Cove on the Texas coast (Bonner, 1996) will further clarify the role of nutrient additions in the biodegradation of crude oil. There have been no similarly scaled studies to evaluate the effects of microbe or microbe + nutrient additions (bioaugmentation). The evidence is lacking that such seeding will enhance biodegradation (Owen 1991). The present inclination of the response community is to favor the technique of nutrient addition rather than bioaugmentation.

RECOMMENDED RESEARCH

1. Conduct statistically credible field studies in a variety of marine coastal ecosystems utilizing EPA permitted intentional releases of oil or spills of opportunity to establish the efficacy and safety of biodegradation enhancement techniques, including nutrient addition and bioaugmentation.

2. Develop nutrient addition guidelines and protocols to include recommendations concerning selection of most effective nutrient formulations, determining background nutrient levels in water and sediment, how best to apply nutrients and how often, what detrimental effects may occur, etc.

3. Develop coastal mapping of locations where bioremediation would be considered in the event of contamination by oil and record the quantitative, seasonal baselines for background levels of nutrients and the numbers and activities of indigenous hydrocarbonoclastic microbial populations at critical locales. Such pre-planning would better enable the response manager to determine whether nutrient addition and/or bioaugmentation are advantageous for enhancement of the intrinsic biodegradation rate.

4. Determine bioremediation effects on microbial communities. The introduction of nutrients and organisms to promote the biodegradation of oil on shorelines may upset the ecological balance on indigenous microbial communities.

5. Develop guidelines for cost effective, "minimally necessary" monitoring protocols for use by response managers engaged in planning and implementing bioremedial projects of varied complexities and coastal locales. Such protocols and their data quality objectives need to be consistent with the operational responsibilities of the response manager.

6. Conduct studies utilizing tiers III and IV Product Treatability Protocols.

7. Develop protocols for conducting spill of opportunity studies, in including strategies for coping with the difficult experimental design requirements and logistics associated with such short lead time events.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.