Box A—bioremediation v. Biodegradation

Biodegradation refers to the natural process whereby bacteria or other microorganisms alter and break down organic molecules into other substances, such as fatty acids and carbon dioxide.

bioremediation is the act of adding materials to contaminated environments, such as oil spill sites, to cause an acceleration of the natural biodegradation process.

Fertilization is the bioremediation method of adding nutrients, such as nitrogen and phosphorus, to a contaminated environment to stimulate the growth of indigenous microorganisms. This approach is also termed nutrient enrichment.

Seeding refers to the addition of microorganisms to a spill site. Such microorganisms mayor may not be accompanied by nutrients. Current seeding efforts use naturally occurring microorganisms. Seeding with genetically engineered microorganisms (GEMs) may also be possible, but this approach is not now being considered for remediating oil spills.

tion of the microorganisms involved in biodegradation had already been developed by the early 1970s. For example, the Office of Naval Research sponsored about 15 basic and applied research projects in the late 1960s and early 1970s on oil biodegradation as part of the charge to the Navy at that time to take the lead in mitigating marine oil pollution. In 1972, a workshop on the microbial degradation of oil pollutants was sponsored by the Office of Naval Research, the U.S. Coast Guard, and the U.S. Environmental Protection Agency (EPA).[6] The 1980s were a period of rapid advances in knowledge of the genetics and molecular biology of bacterial degradation of different hydrocarbons, and of renewed interest in the microbial ecology of pollution-stressed environments.

Much progress has been made in applying basic knowledge of biodegradation to cleaning up terrestrial and enclosed sites polluted with oil. As long ago as 1967, contractors employed bioremediation to improve the quality of 800,000 gallons of oily wastewater remaining in the bilge tanks of the *Queen Mary* after it was permanently moored in Long Beach Harbor.[7] City officials approved the discharge of this bilge water 6 weeks after treatment. More importantly, a large number of refineries, tank farms, and transfer stations now employ in situ bioremediation to restore land contaminated by accidental spills of fuel oil or other hydrocarbons.[8]

Much less progress has been made with respect to the practical problems of applying bioremediation technologies to marine oil spills, although advocates have suggested their use in the wake of several major spills. The problems associated with using bioremediation technologies in marine environments are fundamentally different from those associated with land-based applications. Although bioremediation of oil-contaminated soil is one of the fastest growing uses of this technology, bioremediation applications on land have all been accomplished in closed or semi-enclosed environments where microorganisms have little or no competition and where conditions can be closely controlled and monitored. The marine environment is a dynamic, open system that is much less susceptible to control, and many additional variables exist to compound the difficulties of applying bioremediation techniques. One of the most important series of tests and the first large-scale application of a bioremediation technology in a marine setting was conducted between 1989 and 1991 by the EPA, Exxon, and the State of Alaska on the Prince William Sound beaches fouled by oil from the *Exxon Valdez.*

SUMMARY AND FINDINGS

Biodegradation is a natural process, and there is no question that, with enough time, microorganisms can eliminate many components of oil from the environment. The central concern of this study is whether bioremediation technologies can accelerate this natural process enough to be considered practical, and, if so, whether they might find a niche as replacements for, or adjuncts to, other oil spill response technologies. The key findings from this OTA study are summarized below:

- **The usefulness of bioremediation for marine oil spills is still being evaluated, and their**

[6]D.G. Ahearn and S.P. Meyers (eds.), *The MicrobialDegradation of Oil Pollutants* (proceedings of a workshop at Georgia State University, Atlanta, December 1972) (Baton Rouge, LA: Center for Wetland Resources, Louisiana State University, 1973).

[7]Applied Biotreatment Association, "Case History Compendium,'' November 1989, p. 34. The compendium also Contains other examples of the use of bioremediation technologies to address environmental problems.

[8]T.G. Zitrides, "Bioremediat.ion Comes of Age, " *Pollution Engineering,* vol. XXII, No. *5, May* 1990, pp. 59-60.

Photo credit: Environmental Protection Agency

Prince William Sound, Alaska, site of the extensive bioremediation experiments carried out by the Environmental Protection Agency, Exxon, and the State of Alaska.

ultimate importance relative to other oil spill response technologies remains uncertain. Recent research and field testing of bioremediation technologies on oiled beaches has produced some encouraging, if not altogether conclusive, results. Nevertheless, technologies other than bioremediation (especially mechanical ones) are likely to remain the mainstay of the Nation's response arsenal for now. In certain non-emergency situations (e.g., for cleaning lightly to moderately oiled beaches), bioremediation could be employed as a primary technology. Mechanical methods, dispersants, and possibly in situ burning will most likely remain more appropriate technologies for the immediate response to spills at sea.

- Potential bioremediation approaches for marine oil spills fall into three major categories: 1) stimulation of indigenous microorganisms through addition of nutrients (fertilization), 2) introduction of special assemblages of naturally occurring oil-degrading microorganisms (seeding), and 3) introduction of genetically engineered microorganisms (GEMs) with special oil-degrading properties. Stimulation of indigenous organisms by the addition of **nutrients is the approach that has been tested most rigorously. This approach is viewed by many researchers as the most promising one for responding to most types of marine spills.** Recent experiments suggest that rates of biodegradation in most marine environments are constrained by lack of nutrients rather than by the absence of oil-degrading microbes. The introduction of microbes *might be* beneficial in areas where native organisms grow slowly or are unable to degrade a particular hydrocarbon. However, the effectiveness of this approach has not yet been demonstrated. The wide availability of naturally occurring microorganisms capable of degrading components of petroleum will likely deter consideration of GEMs for remediating marine oil spills. Moreover, greater research and development needs, regulatory hurdles, and public perception problems will remain obstacles to the near-term use of GEMS even if they could prove useful for degrading some recalcitrant components of petroleum.

- bioremediation technologies for beach cleanup have thus far received the most attention. Experiments conducted by EPA, Exxon, and the State of Alaska on cobble beaches fouled by oil from the *Exxon Valdez* indicated that the *addition of nutrients* at least doubled the natural rate of biodegradation. The efficacy of commercial *microbial products in* remediating beaches is not yet known. Limited EPA field tests using two microbial products on heavily weathered oil in Alaska were inconclusive. Additional field experiments are required on other types of beaches that involve different oils and different climatic and marine conditions.

- bioremediation **has not yet been demonstrated to be an effective response to "at-sea" oil spills. The** necessary studies have not been done, in part because of the difficulty of conducting controlled experiments and monitoring in the open ocean. Limited applications have been made in the Gulf of Mexico, but they have not provided definitive data on effectiveness. The design and validation of open ocean protocols to test products are necessary before the efficacy of bioremediation at sea can be determined or widely accepted. Even if bioremediation proves effective in some situations, other, quicker-acting alternatives may be preferable as primary response tools.