UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

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OFFICE OF
THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

EPA-SAB-EPEC-LTR-92-015

Mr. William K. Reilly
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

RE: SAB REVIEW OF THE ALASKAN BIOREMEDIATION OIL SPILL PROJECT

Dear Mr. Reilly,

The Alaskan Bioremediation Task Group of the Science Advisory Board (SAB) has completed its review of the final report on the results of the Alaskan Oil Spill Bioremediation Project. This group met on June 1-2, 1992 to conduct its review. Dr. John Skinner, Deputy Assistant Administrator, Office of Research and Development asked the SAB to review this report and to address several points as part of its review. The charge to the SAB is attached.

The SAB reviewed the preliminary plan for this research in 1989 (EPA-SAB-EETFC-89-023). Since that time, the SAB has received interim updates of progress, so the task group was already aware of many of the results. In addition to the questions that ORD asked the SAB to address, the Task Group addressed issues relevant to how EPA will apply its experience to future oil spills and massive chemical releases that may be cleaned up by bioremediation. Many of the lessons learned from this investigation are of a generic character and can be translated to apply to other types of field studies of deliberately stimulated biological processes.

The Task Group commends the Agency's efforts to rapidly address a significant problem under adverse environmental conditions within a highly complex political and legal framework. The project represents a significant accomplishment which should lay the foundation to improve research and planning for emergency responses in the future.

ADEQUACY OF CONCLUSIONS

The data collected from the test sites in Prince William Sound show that the application of fertilizer solutions to oil-contaminated beaches enhanced oil removal at some locations. It is likely that this removal is attributable to a combination of biodegradation and physical and chemical removal associated with this technique. This bioremediation technique conclusively enhanced oil disappearance at Passage Cove and Elrington Island, had a variable effect at Snug

Harbor, and did not have an effect at Disk Island. The reasons for these differences are not totally clear, but the research does demonstrate the importance of site characteristics in determining the effects of the treatment used for bioremediation. The data suggest that a number of factors affect the outcome of bioremediation efforts. It is likely that with increasing information from more locations and with more microcosm and laboratory research, the controlling factors will be defined as a set of parameters (e.g., porosity of beach materials, beach slope, bioavailability of oil constituents, or fertilizer nutrient ratios), some of which can be modified to allow a greater success rate for bioremediation. The simple comparison below, shows that the sites are not comparable instead they represent individual tests at distinct locations using different fertilizers and application techniques. Thus each site contributes additional information on the effectiveness of the bioremediation technique, but the conclusions from one site may not apply to other locations in a direct manner.

Comparison of Bioremediation Sites

Sites	*Fertilizer Applications/Beach Conditions*	*Oil Loss vs. Control*
Disk Island 1990	*Slow release (B) fertilizer, low slope, sand-gravel beach material*	*No significant difference*
Snug Harbor 1989	*Oleophilic (O) and (B) fertilizers, sites with cobble over gravel and mixed sand and gravel*	*Mixed results, faster loss on cobble, no difference with sand/gravel*
Passage Cove 1989-90	*(O)/Granule (G) and daily fertilizer solution from sprinkler (S), prewashing of cobble and subsurface may have spread oil, increasing exposure*	*Marked increase, sprinkler judged best delivery system, changes in both cobble and subsurface sand and gravel*
Elrington Island 1990	*(S) treatment, focus on subsurface oil, cobble over mixed gravel, high energy beach*	*Marked increase with (S), some loss occurred with (O)/(G) mixture*

Exxon Corporation, the State of Alaska, and other federal agencies (particularly the National Oceanographic and Atmospheric Administration and the U.S. Fish and Wildlife Service) have all collected extensive data sets relevant to bioremediation. We recommend that EPA organize a meeting of the company and agencies to review the findings and reconcile the data sets relative to the critical questions regarding the mechanisms of oil removal at the sites where bioremediation was conducted.

EXTRAPOLATION TO FUTURE SPILLS

The results of the Alaskan Project confirm that microbial biodegradation can be stimulated to bring about the destruction of complex organic constituents of oil, providing the specific decomposers are present among the indigenous microbial populations. The project demonstrated that the use of fertilizers to enhance decomposition of petroleum residuals is a sound approach, providing that treatment designs take into consideration differences in local conditions and the variables that may have an effect on the biodegradation process. One can anticipate, based on the results of the Alaska Project, considerable variation in the degree of bioremediation. A challenge to the Agency lies in taking these results from Prince William Sound and establishing a basis for dealing with future oil spills wherein bioremediation using fertilizers would be the method of choice.

REDUCTION OF CLEANUP TIME

Bioremediation efforts reduced the cleanup time (relative to natural degradation) at sites in Prince William Sound, but the effect of bioremediation was dependent on the particular beach and on the depth of oil penetration below the beach surface. Bioremediation was effective at the Passage Cove and Elrington Island sites, with cleanup reduction times for surface material of the order of 60 to 120 days. Biodegradation of oil occurred at Snug Harbor, but a reduction of cleanup time through bioremediation was not clearly demonstrated. Bioremediation was not effective and a reduction of cleanup time was not shown at Disk Island. The reductions in cleanup time were strongly dependent on location, and the greatest enhancements in bioremediation were observed for subsurface beach material. However, the definition of cleanup time in the report is somewhat confusing. Several indicators of cleanup can be used and these may be based on changes in chemical composition of the oil. The analysis used in the report to demonstrate the reduction of cleanup time is based solely on the loss of total oil.

The conclusion that bioremediation reduced cleanup time must be qualified in view of the high variability in oil chemistry at the sites, the fact that some beaches were prewashed and the fact that the oil was continuously aging and weathering during the bioremediation period. Moreover, the specific estimates of cleanup time given in this report have considerable statistical uncertainty. Quantification of the effect of bioremediation is difficult because of the limited number of sites that received different treatments and the fact that the sites had different geological characteristics.

ADEQUACY OF SUPPORTING RESEARCH

Considerable supporting research was performed that yielded data important for making operational decisions necessary for the field operations. However, much of the supporting research was insufficient to interpret the field results, since --- if for no other reason --- the field results were often not fully available at the time that the supporting research was designed and conducted. To maximize the effectiveness of future bioremediation efforts, laboratory and microcosm research should be conducted with a view to providing the needed explanations.

SELECTION AND TESTING OF FERTILIZERS

Major constraints existed at the time that selections had to be made on the specific fertilizers to be used. These constraints included the absence of a body of directly relevant information for circumstances at the Alaskan sites and the lack of availability of sufficient quantities of fertilizers that might be of possible utility. Similarly, testing procedures specifically designed for evaluating fertilizers to be used on beaches had not been devised and validated.

Further research should be conducted to determine which components in the fertilizer stimulate removal of oil. Given the limitations, we believe that EPA made reasonable choices in selecting and evaluating the fertilizers. However, in light of the apparent effects of fertilizers in enhancing biodegradation, it is essential that a research and development program be implemented to determine the types of fertilizer materials, formulations and composition needed to optimize the rate and extent of bioremediation, to devise testing procedures that will permit evaluation of the fertilizer materials for the likely types of spill sites and to develop fertilizer application methods most useful for various sites and types of oil spills.

SAFETY OF BIOREMEDIATION

The Agency conducted an assessment of the safety of bioremediation and evaluated possible ecological effects. The chief ecological issue of concern was the potential impacts of nitrate and phosphate fertilizers applied during the bioremediation activity on the structure and/or function of the near-shore marine community. The potential mechanisms of impact include acute toxicity of ammonium, eutrophication resulting in low dissolved oxygen, nutrient enrichment of the waters resulting in blooms of algae and the bioaccumulation in marine benthic food chains of intermediate compounds formed during biodegradation. A second issue involved the potential redistribution of the oil residue back into the offshore aquatic environment.

Assessments were performed of acute toxicity and potentials for eutrophication. The maximum ammonium concentration observed in the water immediately adjacent to the test plots was 0.035ppm, which is well below the estimated standard for chronic toxicity of 8 ppm. The nutrients released from the bioremediation test sites did not appear to significantly enhance the available nutrients in near shore waters. The issue of redistribution of the oil residue was addressed by placing mussels in cages on the bottom in areas adjacent to the test plots. Mussels filter fine particles and are good bioaccumulators for adsorbed residues. The distribution of solubilized oil residues were not monitored. Major changes in phytoplankton abundance and productivity were not observed. Changes in benthic algal abundance and algal species were not monitored. Such monitoring would have been useful for nutrient loading or the redistribution of oil residues to adversely affect food availability for filter feeders or to stimulate toxic dinoflagellates. The bioaccumulation pathways were identified through the use of stable isotopes of carbon and nitrogen. Direct measurements of oil residues at various levels in this food chain were not made because EPA reasoned that since the oil residues had been weathered for at least 6 months before the bioremediation was initiated, there was little need to analyze for bioaccumulation. Given the site-specific conditions of this Alaskan ecosystem, the timing of the onset of bioremediation, the limited areas of fertilizer application and the limited application rates, adequate field information was gathered to conclude that the bioremediation effort would not negatively impact the Prince William Sound ecosystem. Furthermore there was no demonstrable evidence of adverse impacts. The potential for impact is site specific.

The methods developed for assessing environmental safety of the program can provide a foundation for future assessments but should not be considered sufficient by themselves for all situations. The environment of Prince William Sound is unique in many ways, and additional testing may be required on a site-specific basis. Factors to be considered should include: type of beach in terms of particle size and slope; energy of the system, both from tides and wind; sensitive species, habitats and communities; timing of a cleanup event relative to ecological utilization of the site; trophic structure and potential for food chain transport of metabolites through food chains; potential for eutrophication, particularly long-term adverse effects; potential for induction of anaerobic conditions; and potential for human exposure.

These issues can best be addressed by performing initial site-specific risk assessments (both human health and ecological), as was done by EPA in this project, to estimate the relative importance of exposure pathways and the relative sensitivity of various biological endpoints. These data can be used to determine if the suite of tests employed are adequate or if additional site-specific tests should be added. These types of assessments should be carried out soon as part of a research program for oil spills so that ecosystem specific suites of tests can be established. This approach would be particularly important for sensitive environmental habitats such as coral reefs, mangrove swamps, and salt marshes which would be particularly sensitive to oil spills.

BIOREMEDIATION STRATEGIES FOR FUTURE OIL SPILLS

As would be expected from research implemented during an emergency response, the data gathered in the Alaska Bioremediation Project are highly variable in both quantity and quality depending on location, site, and experimental protocol employed. However, the research conducted during the course of this project represents an important first step in developing a scientific basis for strategies to deal more effectively with future oil spills. Nevertheless, the data from the Alaska Bioremediation Project need further analysis to carefully differentiate between conclusions drawn from data sets that differ greatly in quality.

The lessons learned from Alaska are manifold, but many are probably unique to the location, temperature, seasonal cycles, type(s) of shore, etc. Transfer of the technology to other locations may be thus limited to generic issues only, and caution should be exercised in applying the methods and approaches used in Alaska to other locations. For example, fertilizer addition clearly enhanced the rate of oil removal in some instances and not in others, but the data do not provide an adequate basis for deciding when to apply fertilizers to oil spills (i.e., shortly after the spill or some time later) in more temperate climates or to beaches with higher contents of sand and organic matter or in less energetic areas with longer hydraulic detention times, etc. Hence, considerable research will be necessary to identify the causes of variability in different spill scenarios. Systematic analysis of spill events will both indicate where the information gained in Alaska can be best applied and provide guidance for prioritizing future research needs for wide scale use of bioremediation for oil spills.

The measurements performed in the bioremediation project were a good initial approach to quantifying the effectiveness of the treatments. Nevertheless these measurements have limitations. With further development some offer great promise. Chemical analyses of total oil remaining (gravimetric), hydrocarbon composition (GC and GC-MS) and nutrients are essential to understanding the fate of the oil and need for and effectiveness of nutrient additions. Measurements of microbial activity suitable for use in the field need further development. The Task Group is not convinced of the usefulness of measurements of microbial biomass in the field, and also cautions EPA that use of predation models to explain observed biomass is likely to be unproductive. The measurements should be developed and evaluated in the context of specific hypotheses to be tested. Research will need to be undertaken to adequately develop and assess the efficacy of all measures used to quantify the success of bioremediation.

DATA INTERPRETATION

A large amount of useful data was collected by the Alaska Oil Spill Bioremediation Project. If these data are to be used to their fullest extent, rigorous interpretation is essential. Only in some of the field studies was convincing evidence of bioremediation obtained, yet many of the summaries and conclusions read the same. The document should be revised to clearly distinguish the data that show bioremediation and those that do not. Much could be learned from careful studies in which bioremediation was not successful. The role of chemical and physical factors in removal and degradation of oil in addition to and/or in concert with biodegradation also needs to be more clearly discussed.

OVERVIEW CHAPTER

The report of the Alaska Oil Spill Bioremediation Project contains an immense amount of data. Most readers, however, will be unable to assess the results of the project because of the enormous amount of detailed information. Thus, a chapter is needed that gives an overview of the issues, the purpose of the program, the methods used, the major findings, the problems of variability of the data from field assessments, the ecological hazards that may have been minimized or prevented, and the conclusions that are particularly pertinent for future bioremediation. This chapter will not only be useful to the general reader but will give guidance to the specialist who indeed will read the full report. That chapter probably would be best placed before the detailed presentation of methods and results.

TESTS AND MEASUREMENTS

Many measurements have been made, and several types of tests have been conducted as a prelude to field activities or to permit interpretation of those field activities. Undoubtedly, some of these measurements and tests were essential. It is also likely that hindsight will show that some of the chemical, microbiological or ecological measurements or tests that were conducted were not really necessary and that other measurements or tests should have been performed. EPA should make such determinations and propose a revised suite of measurements and tests for future oil spills and for the supporting research. Particular attention should be given to the tests and analyses that should be conducted in the short time period between the time of a spill and the time when field bioremediation should be initiated.

STATISTICAL DESIGN AND ANALYSIS

Large-scale applications of bioremediation technologies in heterogeneous environments require detailed consideration of experimental design, data management systems and statistical analyses. The physical heterogeneity of the sites in Prince William Sound is likely to be encountered often in the future. Alternative statistical designs range from stratified analysis of variance with suitable replications to multiple regression, which maximizes the range of environmental characteristics.

Parametric analyses should be utilized that provide confidence intervals on rates and endpoints of bioremediation. The process and endpoint parameters must be identified before the appropriate experimental design can be chosen. The number of replicate samples, the range of stratified conditions, the frequency of monitoring samples and the number of treatments being tested at any point in time are all dependent on the experimental design of choice. These decisions all must be explicitly made before any field activities are initiated.

Since oil spills are episodic events that can not be predicted ahead of time, the Task Group recommends that specific alternative design and analysis strategies be considered now for various classes of ecosystems as part of EPA's remedial-response planning process.

MODELING

Mechanistic models of bioremediation technologies based on fertilizer applications must be developed that reflect state-of-the-art capabilities (e.g., fate and transport processes, critical analytical data, and metabolic rate processes). These models will be essential for the engineering design required for scaling the activity from test plots to full-scale remediation. The mechanisms required in these design models must involve transport, fate and storage phenomena. The models can be parameterized and validated using laboratory and field microcosms, stable isotope analyses of field experiments, and mass transfer/balance measurements obtained during remediation projects.

The attempt to develop predator/prey models of protozoa and bacterial biomass during bioremediation is inappropriate at this time, because the effect of protozoa is unknown. Bacterial biomass is not the appropriate state variable, and the reported modeling activities are not the most productive alternatives.

ORGANIZATION AND MANAGEMENT

We highly commend the EPA staff that organized and managed the project. They planned, initiated, and conducted a research program of which the Agency may be proud. Nevertheless, considering that the Exxon Valdez spill will not be the last oil spill, EPA should evaluate the effectiveness of the organizational structure used for this project for its relative success, the problems it encountered and ease of operation so that future initiatives can be the most productive. EPA should consider the value of having a rapid response group (including aquatic physical scientists, microbiologists, environmental toxicologists, chemists, and statisticans) to undertake research that could be initiated under emergency conditions such as those experienced in Prince William

Sound. This might provide opportunities to rapidly improve on approaches and management strategies that could increase the efficiency of bioremediation under emergency conditions.

We appreciate the opportunity to review this completed project and look forward to receiving the final documents. In particular, we are interested in how EPA applies this experience as guidance for selecting appropriate responses to oil spills in the future and for planning further research to improve field monitoring, including its statistical design.

Sincerely,

Raymond Loehr, Chair
Executive Committee
Science Advisory Board

Kenneth L. Dickson, Chair
Ecological Processes and
Effects Committee

Martin Alexander, Chair
Alaskan Bioremediation
Task Group

Attachment

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ALASKAN BIOREMEDIATION TASK GROUP
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MRS. MARCIA K. JOLLY (MARCY), Secretary to the Designated Federal Official

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MEMORANDUM

MAY 15 1992

SUBJECT: Charge to the Science Advisory Board for Review of the Alaska Bioremediation Project

FROM: John M. Skinner /S/
Deputy Assistant Administrator
for Research and Development (RD-672)

TO: Donald G. Barnes, Director
Science Advisory Board

I offer the following questions as a charge to the panel that will be reviewing the results and conclusions generated in the Alaska Bioremediation Project:

- Do the data and interpretations adequately support the conclusions that bioremediation was directly responsible for the enhanced disappearance of oil from the beaches and that under similar conditions, disappearance of oil can be enhanced on other types of contaminated beaches?

- Based an disappearance rates for oil residues, coupled with large changes in oil composition, did bioremediation substantially reduce cleanup time of oil-contaminated beaches, thereby justifying its large scale use on the Prince William Sound shoreline?

- Were adequate supporting research studies performed to allow proper interpretation of field results?

- Were the selection and testing procedures for fertilizers appropriate for the demonstration of bioremediation on Prince William Sound beaches? Does SAB agree that these procedure have future application?

- Was sufficient research performed and field information collected to conclude that bioremediation in Prince William Sound was safe and did not result in any adverse ecological effects? Are the methods developed for assessing the environmental safety of bioremediation on oil-contaminated beaches appropriate as a foundation for future assessments?

- Based on the response of the spilled oil to bioremediation, should future responses be planned and contingencies developed? Is the data also generated from the Alaska Bioremediation Project sufficient to use as the basis for the development of bioremediation strategies that can be applied to future oil spills? Is it appropriate to develop measures of effectiveness for future oil spill bioremediation efforts using combination of gravimetric, chemical (oil and nutrients), and microbial (biomass and activity) measurements?