Report of NABIR Subcommittee of BERAC

October 8-9, 2001 meeting at AGU, Washington D.C.

Biomolecular Science and Engineering Element

The Biomolecular Science and Engineering Element supports a diversity of forward-looking research projects that are investigating important aspects of microbe-metal interactions and the survival of microorganisms in subsurface environments. The NABIR program has a strong need for this element of basic science that will further the understanding of the mechanisms by which microorganisms can immobilize metals in subsurface environments. Furthermore, metabolic engineering of microorganisms with novel strategies for sequestering metals or enhanced capacities for survival in harsh subsurface environments could expand the range of contaminants and environments that are amenable to bioremediation. The committee's responses to the questions posed by DOE (bold) are below.

Are the current thrusts in this element appropriate?

The research in the Biomolecular Science and Engineering Element has been appropriate and of high quality. Support has been provided for investigations into a relatively broad range of potential microbe-metal interactions and survival mechanisms. This was the appropriate strategy when there was little information on which approaches and which microorganisms might be most suitable for the in situ bioremediation of a broad range of contaminants.

However, the Strategic Plan for the NABIR program has recently been focused on the immobilization of a restricted number of target metals. In considering the research needs for this element, it is useful to consider the target environmental contaminants into groups that present common challenges. For the key contaminants, uranium and technetium, a likely bioremediation strategy has emerged. Research projects in the Biotransformations and Biogeochemistry elements have demonstrated that establishing anoxic conditions are essential for the immobilizing uranium and technetium. Projects in the Community Dynamics Element have provided information on which microorganisms are likely to be involved in the reductive immobilization of uranium and technetium in subsurface environments. Furthermore, all results to date have indicated that indigenous microorganisms can effectively precipitate these metals once the appropriate geochemical conditions are established.

Therefore, in the areas of uranium and technetium bioremediation, the Biomolecular Science and Engineering Element could better support the needs of the other NABIR elements in the future by directing research efforts toward a better understanding of the physiology of the microorganisms expected to be important in uranium and technetium reduction in subsurface environments. For example, although studies on the mechanisms of survival of microorganisms in nutrient-limited environments are clearly pertinent to NABIR objectives, ideally future studies in this area should be carried out on microorganisms which projects in the Community Dynamics Element have demonstrated (or demonstrate) are involved in subsurface bioremediation of metals. In a similar manner, detailed investigations into the enzymatic mechanisms for metal reduction are necessary in order to better understand this process in the subsurface and to identify gene targets that will permit better molecular assessment of metal reduction. However, such studies should also be targeted to microorganisms that have been demonstrated to play an important role in metal reduction in subsurface environments. This is especially important now that it is becoming apparent that phylogenetically distinct metal-reducing microorganisms may have significantly different mechanisms for metal reduction.

For mercury and plutonium, two other contaminants targeted by the NABIR program, the likely strategies for in situ immobilization are less clear. For example, indigenous subsurface microorganisms are known to reduce Hg(II) to Hg(0), but this volatilizes mercury, not a useful approach for immobilization. Thus, in situ bioremediation of mercury and plutonium may require the use of microorganisms specifically engineered to sequester these metals. However, it is important that the metabolic engineering aspect of the Biomolecular Science and Engineering Element be guided by practical considerations, i.e. the organism and process requirements should match those needed and feasible for the environment. For example, radiation resistance is not likely to be a primary consideration for the bioremediation of the majority of contaminated DOE subsurface sites, because the levels of radiation are well within the limits tolerated by most microorganisms. Engineering pathways for aerobic metabolism of organic contaminants to serve as electron donors for anaerobic metal reduction in the same organism, or for the aerobic formation of sulfide-metal precipitates that are likely to rapidly reoxidized by oxygen should be further evaluateed to determine their suitability for in situ application.

It is not clear that further investigation of the biological reduction of Cr(VI), the other metal contaminant of concern for NABIR, are of immediate need. Although many microorganisms can reduce Cr(VI), it is also rapidly reduced via abiotic mechanisms.

Studies at the FRC have demonstrated that microbial reduction of nitrate and metals at low pH are likely to be key concerns for the remediation of uranium and technetium at some DOE sites. Therefore, as microorganisms involved in these processes at low pH are identified further investigation into the mechanisms for reduction of nitrate and metals at low pH may be warranted.

How can DOE better integrate research in this element with other NABIR elements and other BER programs, especially the genomic programs?

As mentioned above, research more focused on the Strategic Plan goals and FRC needs will provide a more coherent focus on target, processes and organisms and hence increase the common interfaces for projects among elements. Examples of needs deriving from new FRC information or identified in the strategic plan that could be directly relevant to the Biomolecular and Engineering Element include: (i) understanding of basic mechanisms of metal reduction and reoxidation, (ii) bioprocesses under acid regimes, (iii) bioprocesses under very high nitrate regimes, with and without acid, (iv) understanding sustainability of immobilization

The Biomolecular Science and Engineering Element of NABIR serves a function that is related, but distinct from the Microbial Genome Program and the Microbial Cell Project. Whereas projects in the Microbial Genome Program and the Microbial Cell Project generally focus on the overall basic physiology of microorganisms, some of which are of direct interest to the NABIR program, the Biomolecular Science and Engineering Element provides the opportunity for in-depth investigations into aspects such as mechanisms for microbial metal reduction and growth and survival in subsurface environments that are of direct applicability to the NABIR program.

The next phase of NABIR would benefit from a more advanced level of interaction among the scientists in different elements. In the past meeting together and hearing about research in other elements has sufficed to inform but it does not provide the level of detailed consideration and discussion need for the next stage of more integrated and field relevant research. This goal is probably more challenging for the basic molecular scientists because their area of research is more distant from that of the geochemist or field engineer. Mechanisms to consider for stimulating a higher level of interaction could be: (i) NABIR managers and perhaps an FRC science leader develop a more goal oriented and sustained mechanism for the interactions, (ii) the RFP and reviewer information ask for more insight into the problem and the eventual relevance of the research than the common superficial text often provided for relevance, and (iii) perhaps develop problem-oriented, multidisciplinary teams that focus on the key problems and conditions that are now better defined.

Are there opportunities and needs that are being overlooked?

This element has the potential to provide novel, creative approaches to the more difficult problems, and hence such projects should be encouraged. Areas that now appear important and may be overlooked include; (i) biomolecular research on microbes important in indigenous communities, (ii) studies important to acid regimes, and (iii) novel mechanisms to immobilize mercury and plutonium.

Signed for the Committee

James M. Tiedje, Chair November , 2001

Members present:

Linda Abriola
Margaret Cavanaugh
Linda Chrisey
Stephen Lien

Derek Lovley
David White
Ray Wildung
Ken Williamson
Amy Wolfe
John Zachara