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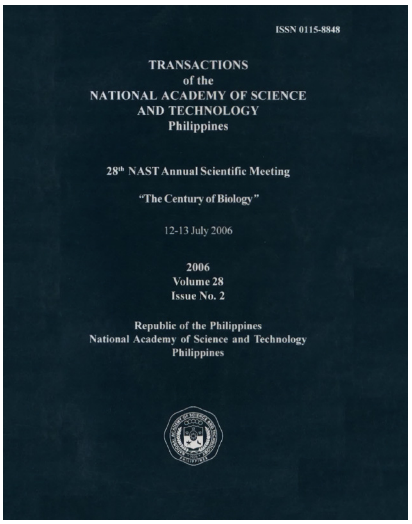

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Bioremediation: A Proven and Cost Effective Tool for Repairing the Environment

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BIOREMEDIATION: A PROVEN AND COST EFFECTIVE TOOL FOR REPAIRING THE ENVIRONMENT

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Abstract

About twenty years ago, bioremediation, the art and science of harnessing the natural metabolic processes of everything from simple microorganisms to plants, to destroy or sequester contaminants, became a real option. The potential to engineer these processes created a new alternative to capital and management intensive mechanically-driven protocols and a thriving industry arose to serve this new strategic approach. We are now experiencing a maturation of this "era of bioremediation", which is further being accessorized with in-situ thermal and chemical oxidation processes for more rapid initial site impacts. Taken all together we are moving into an "era of in-situ treatment", but regardless of how one intervenes with thermal or chemical energy in a contaminated area, biological processes ultimately are needed to finish the operation. Further, there have been many exciting new developments in molecular biology that are now enhancing the science of bioremediation, such that with a more refined understanding of key biological players and processes we can better design and manage bioremediation engineering.

The Republic of the Philippines is like any other with a modern economy- it has severe environmental problems that have reached crisis proportions. However, as an island nation with limited territory, these problems have a special insidious feature; there is no place to run. Fortunately, with the help of powerful natural processes like bioremediation that work around the clock without supervision we have the tools to heal the environment cost-effectively. Consequently, the National Academy of Science and Technology formed a Bioremediation Research Team (BRT), which, after a series of meetings, decided to focus on unattended sources of hazardous wastes, with a special emphasis on the problems of the mining industry.

The issuance of Executive Order No. 270 – the National Policy Agenda on Revitalizing Mining in the Philippines, (January 16, 2004), and the favorable Supreme Court decision on the Philippine Mining Act 7942 of 1995, have led to the revitalization of the local minerals industry, which had become nearly dormant prior to the decision. Such decisions elicited hope in both public and private sectors that a revitalized mining industry could boost the economy; however, there are two main issues attached to the mining industry: abandoned mines and the management of mine wastes. How can bioremediation help? Well, from the top down, we have phytoremediation which harnesses the healing aspects of plants for the more surficial aspects of these abandoned mines while subsurface engineered biological barriers, which rely on microorganism activity, address contaminated aquifers.

The BRT proposes to conduct a project on Field Test Applications of Phytoremediation and Microbial Technologies for the Rehabilitation of Contaminated Mine Sites. This project will utilize established heavy metal resistant plants. Jatropha curcas, commonly known as "tubang bakod", is a prime candidate as it thrives in marginalized land and the nuts can be used as source of biodiesel.

Other projects on "The Use of Local Bioremediation-based Technologies for the Management of Wastes from the Mining Industry" are also being proposed. The BRT, composed of microbiologists, chemists, botanists, foresters, and plant biologists, believes that bioremediation projects are worth pursuing should funds become available.

Keywords: bioremediation, waste management, mining, BRT, Philippine Mining Act 7942

At the turn of the millennium, there was a human interest feature in the presence of centagenarians who were now traversing three centuries of existence. A parallel is drawn to environmental professionals who if present in the 1990s would have traversed three decade-long eras in groundwater remediation. In the 1990s, we were at the twilight of the first "era of mechanical intervention" and this transitioned to the "era of bioremediation". Now we are experiencing the advent of a third era that emphasizes a long overdue hybrid of advanced diagnostic tools that help in the design and management of in-situ remediation processes that employ physical and biological oxidative or reductive processes in "treatment trains". Further we are also starting to harness the power of plants as well as microbes as agents of remediation.

In the "era of mechanical intervention", engineers practiced the art and science of digging and hauling or pumping and treating essentially to the exclusion of all else. Environmental engineering was a design, capital and operationally intensive affair. It was in the moment a logical starting point, and while these methods are well preserved and certainly have their place in the pantheon of treatment options, by force of necessity practitioners began to develop more refined in situ approaches. The power of natural biological processes in remediation was recognized and the potential to engineer them created a new pathway; an industry arose to form and serve the new thinking. Arguably, we are now experiencing a maturation of this "era of bioremediation", and are further witnessing that it is being accessorized with thermal and chemical oxidation processes for a kick start on palpable sources. Perhaps reference should be made to an "era of in-situ treatment", but it is more comfortable to use the first characterization featuring bioremediation, because regardless of how one begins in situ treatment, biological processes ultimately are the closing act.

Bioremediation is a technology that uses organisms (i.e., microbes and plants) to reduce, eliminate, contain or transform to benign products contaminants present in soil, sediments, water and air. Bioremediation is an excellent technological solution to environmental problems and associated impacts to human health and the ecology in general. The nature of the contaminant determines the bioremedial process and it is good to know that there is no compound, whether anthropogenic or natural, that microorganisms cannot degrade. Aerobic bioremediation which requires oxygen is applicable to petroleum hydrocarbons and other aerobically degradable compounds. On the other hand, anaerobic bioremediation can be used for chlorinated solvents and other anaerobically degradable compounds and both processes can be employed for the transformation and precipitation of metals

A concrete example of a bioremediation technology for field application is the use of various solutions of fermentable carbon (organic acids, sugars, etc.) which can be easily injected into the aquifer using direct-push technologies. In one specific example, a time-release lactic acid product was used in treating a 14-acre manufacturing site in Southern California contaminated with chlorinated solvents dominated by perchloroethylene (PCE). An existing pump and treat system was ineffective and caused problematic migration of PCE and so the lactic acid polymer was applied by injection. Anaerobic conditions which support organisms that metabolize chlorinated solvents were created and a substantial decrease in PCE from greater than 20,000 mg/L to 261 mg/L was achieved. The rest was left to natural attenuation and the pump and treat system was shutdown for a cost savings of over $1M.

There are other methods of bioremediation that are "ex-situ" in nature. This modality involves the use of "biopiles" or "land farming", the latter used in conjunction with the use of plants, i.e., phytoremediation. Biopiles involve the biological treatment of above ground mounds of excavated soils by addition of moisture, nutrients, air, or organisms. Land farming is a process of biologically treating uncontained surface soil, usually by aeration of the soil (tilling) and addition of fertilizer or organisms, hence the term farming. Phytoremediation involves the use of selected plants to metabolize and destroy contaminants either in an undisturbed system or as a polishing step to land farming.

In the Philippines, a Bioremediation Research Team (BRT) has been established under the auspices of the National Academy of Science and Technology.

The issuance of *Executive Order No. 270* – the *National Policy Agenda on Revitalizing Mining in the Philippines* last 16 January 2004 and the favorable Supreme Court decision on the Philippine Mining Act 7942 of 1995 have led to the revitalization of the local minerals industry, which was nearly dormant prior to the decision. Such decisions elicited hope in both public and private sectors that a revitalized mining industry could boost our economy. There are two main issues attached to the mining industry: abandoned mines and the management of mine wastes. Although some sectors of the mining industry claim they do not pollute the environment, still environmental and health issues persist. The BRT contends that a balance between industrialization and preservation of the environment is possible and advocates bioremediation as the appropriate approach to meet the challenge posed by these pollutants.

To help resolve these impending problems, a project on Field Tests of Phytoremediation and Microbial Technologies for the Rehabilitation of Contaminated Mine Sites is being proposed. An inventory of heavy metal resistant plants that can be used for phytoremediation and of technologies to ensure higher survival rate of seedlings (microbial inoculation) is currently available. Species that can be planted in abandoned mines have been identified and research on how to increase the survival rates of plants for phytoremediation, such as the use of microbes to promote rapid plant growth, consequently increasing the survival rate of plants even under stressed conditions are being undertaken. *Jatropha curcas*, locally known as "tubang bakod", is a prime candidate as it thrives in marginal land and its nuts can be used as source of biodiesel. Research programs for Jatropha production and utilization as alternative energy source are being undertaken.. The potential of the *Jatropha* plant as a phytoremediation species is enhanced with microbial inoculation.

A microbial-based bioremediation technology is being developed for heavy metal contaminated waste water by Drs. Fidel Rey Nayve Jr. and Catalino Alfafara using bacterial cell component (eps)-malunggay (*Moringa oleifera*) seed complex. This involves growing the bacterium, *Rhizobium*, in an indigenous medium like coconut water. The bacterium grows and produces the extrapolysaccharide compound, EPS, which will then be extracted and introduced into the effluent. EPS will bind the metals and the complex will remain suspended in the effluent. With the addition of malunggay seeds extract, a complex is formed between the extract and the heavy metal-EPS which will flocculate and can be collected. The effluent will become a clear liquid devoid of heavy metal contaminants, which can then be released into a body of water. Other microbial based technologies are also being proposed.

Bioremediation, as a field, is relatively new in the Philippines. With the continuing degradation of the environment on account of pollution, it is imperative that bioremediation, as a cost-effective mitigating measure, be seriously considered. Established technologies have to be tried to ascertain their applicability to local conditions. We hope that such kind of research, aimed at managing pollution in our country, can receive the necessary support.