



**BIOREMEDIATION: A
POTENTIAL STRATEGY
FOR MINING WASTES
MANAGEMENT**

**The National Academy
of Science and Technology**

December, 2006

NAST monograph series 31



**THE NATIONAL ACADEMY OF SCIENCE
AND TECHNOLOGY (PHILIPPINES)**

FOREWORD

Pollution is an increasingly serious problem in all over the world. In the past, this was considered an inevitable cost of progress. Such a line of reasoning is now becoming difficult to sustain because the worsening health and environmental costs are beginning to outweigh the perceived benefits of “development.” With the increased incidence of diseases ranging from emphysema to cancer, and incidents like the Payatas tragedy and the Marcopper incident, there is increasing public pressure to take decisive action on the issue.

The expected revival of large-scale mining as a consequence of the approval of the Mining Act brings numerous opportunities for the industry and the country as a whole, while presenting several challenges, among them pollution brought about by mining wastes. Bioremediation is one approach that can be taken to minimize and contain pollution and rehabilitate sites contaminated with mining waste. Recently, talks with executives of the mining industry indicated interest in developing technology for the bioremediation of mining wastes. Since mining is now in the limelight, it was decided to focus on mining wastes

The National Academy of Science and Technology (NAST), whose mandate includes advising the Office of the President on matters of science and technology and lending its scientific expertise to the solution of national problems, thus organized a Roundtable Discussion (RTD) on Bioremediation of Mining Wastes. The objectives of the RTD were to bring together stakeholders and experts on various aspects related to mining wastes, to present possible bioremediation strategies and get feedback from all concerned and to establish contacts, networks, and linkages which will contribute to the search for a solution.

This monograph contains the different papers presented during the RTD on Bioremediation of Mining Wastes held at the Traders Hotel on April 7, 2004.



EMIL Q. JAVIER

President, 2005 - 2008

National Academy of Science and Technology

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WELCOME REMARKS

ACD. PERLA D. SANTOS OCAMPO

President (1999-2005)

National Academy of Science and Technology

Good morning to all of you. I guess we're all at war. We are at war against toxic and hazardous waste. I guess that's the symbolism. I would like to say that this is a very distinguished group, and we're happy that you are all here to help us resolve some issues and guide us on how to put forward the issue of bioremediation of mining waste.

There are quite a number of distinguished speakers here now. We would like to thank you for coming to help us. I would also like to mention Leonarda Camacho, who is very much into environmental protection, and also of course, Walter Brown, the son of my favorite chemistry teacher at UPIS. He is in geochemistry, so he can speak the lingo of most of our speakers. Since he has had his Ph.D. in Geochemistry at Stanford University, he is now COO of Philex Mining, a very environment-conscious company.

Today's session should be started off by saying that we have a paradox here in the Philippines. We keep saying that we are poor, but on the other hand we are actually very rich in mineral resources. We are rich in natural resources, including of course our mineral resources. According to the 2000 US Geological Survey Minerals Yearbook, our country ranks among the world's top ten in the production of chromite, copper, gold and nickel. It may also interest you that there are several new rich mines in the Philippines. For instance, the site in Coto, Zambales is known to have the largest deposits of refractory chromite in the world. Dr. Brown tells me that there are new ones – I don't know if this is confidential information. Anyway, there is one that is very rich in Mindanao, and of course, Rapu-Rapu in Bicol.

We saying, however, that mining has its downside, mainly in the form of pollution. That is why Mrs. Camacho is also with us. This is because of the pollution produced during the extraction and processing of minerals from the soil, resulting in serious consequences to health and the environment. Toxic and hazardous waste hot spots have become so

widespread in the country, from cyanide poisoning in the Cordillera in Northern Luzon to mercury accumulation in Compostela Valley in Mindanao, that the image of the entire industry has taken a very serious beating. It hasn't helped that the largest mining disaster of its kind in the world, the Marcopper catastrophe, caused so much environmental deterioration in Marinduque.

Such incidents have produced a serious backlash. Because of these, there has been a consequent loss of jobs and revenue at a time when our government, our people and our country badly need to generate income and stimulate the economy.

But now we see positive issues that can help. One of these is of course going to be discussed at this roundtable. The Bioremediation of Toxic and Hazardous Waste Task Force created by the NAST in response to all of these problems is headed by Dr. Asuncion K. Raymundo, who has been in touch with all of you. Dr. Javier, who has been President of the University of the Philippines, now Vice President of NAST, and Dr. Ruben Villareal, who was previously Chancellor of the University of the Philippines Los Baños, are with us today. We are very much interested in this, and therefore the Task Force held a seminar-workshop on toxic waste bioremediation in March 6, 2003. The group has conducted visits to various THW sites, collected and analyzed samples, prepared proposals, tackled various aspects of the problem, utilized the multidisciplinary expertise of its members and met with various members of the mining industry.

Another cause for optimism is the recent favorable Supreme Court decision on the Mining Act. This promises a revival of the mining industry after a prolonged hiatus. Already, there are signs of fresh investments. We already know that from local and foreign sources. We see that in our stocks going up. This bodes well for the government, which is struggling with a huge budget deficit, as well as a citizenry grappling with inflation and unemployment.

This time, however, we hope that the wisdom brought by experience and hindsight will help us to avoid the pitfalls that we encountered in the past while protecting our environment.

One such technology which is available to us in order to protect our environment is bioremediation, and this is what is going to be discussed today. A short definition of bioremediation is that it is the process of using biological organisms to solve an environmental problem such as contaminated soil and groundwater. Commercial applications of bioremediation in the mining environment include immobilization and recovery of soluble metals from aqueous water and the microbial degradation of cyanide species. Other types of bioremediation exist and are often employed for the treatment of hydrocarbons in groundwater. The systems employ microorganisms to treat the contaminants.

The National Academy of Science and Technology, therefore, through the NAST Toxic and Hazardous Waste Management Committee in cooperation with the Philippine Council for Industry Research and Development represented here has deemed it necessary to organize this roundtable in order to address issues and concerns surrounding the mining environment. This can be the beginning of an opportunity for the mining industry to project an image of an environment-friendly, socially-responsible ally fully committed to national development. With other stakeholders, including government, the academe, non-government organizations and local residents, let us all join hands to contribute to the promotion of the welfare of the country while bringing about progress and prosperity. So, welcome to you all, and we hope that at the end of this discussion, our objectives of incorporating inputs from all of us, from all these stakeholders and experts, will allow us to come up with strategies which are safe, workable, cost-effective, scientifically sound, environment-friendly and acceptable to all parties concerned. So thank you very much once again for coming. Welcome and mabuhay po.

UPDATE ON THE ACTIVITIES OF THE CHAMBER OF MINES

Ms. Nelia Halcon
Executive Vice President
Chamber of Mines

Secretary Alabastro, our Director, Dr. Walter Brown, the distinguished scientists from the science community, a pleasant good morning. Our president, Philip Romualdez, is unable to make it because of previous commitments. And what he would want me to do is to discuss with you and give you an update on the activities of the Chamber of Mines in coordination with the government and then perhaps the concerns of the management of the mining industry. I am still waiting for the report of our environment committee, so what we will be discussing in this roundtable discussion is on a case-to-case basis, since each mine has its own peculiarities in terms of managing its own waste.

Incidentally, I would like to correct a misconception that mine waste, or the tailings, are toxic. They're not. And before the waste is placed into the tailings dam, the water with it has already been recycled and freed from waste.

The Supreme Court's decision on December 1, 2004 confirming the constitutionality of the Mining Act of 1995 indicated the collective consensus of all three levels of government to actively promote and develop the mining sector as an engine of economic growth in the country.

With this opportunity, the Chamber of Mines of the Philippines organized a high-level international mining investment conference last February 2 to 5 at the New World Hotel informing the international community that the Philippines is open for business, and that the country is committed to protect mining investment – as well as of course the environment. In spite of only two-months' preparation, the response to the conference was overwhelming. With the unexpected number of high-level CEOs and key executives of some 50 major mining companies coming from nine countries attending, the conference generated at least 29 MOUs and LOIs with local partners, which would ultimately translate to about P5 billion in investments, fully initialed 23 pipeline projects that were

promoted, as well as other projects in the mature stage of exploration.

In advocating responsible mining under the framework of sustainable development, a parallel NGO-stakeholders' forum which had open dialogue and collaboration was simultaneously held in Malacañang. The result of this forum was equally successful because a consensus was reached by the participants that responsible mining can be realized with the involvement of all the stakeholders. Prior to the two-day conference, a mining investment road show was held in China by the government and the private sector, which, as expected, generated a lot of interest, considering the huge market demand of the said country for minerals and metals. This road show resulted in investment pledges in Philippine mining projects amounting to some US\$1.3 billion by Chinese companies. *Two MOUs were signed between the Department of Trade and Industry (DTI) and the China Ministry of Commerce, and between the DENR and the LCC China Metallurgical Construction Corporation.* LCC also filed a letter of intent for an initial investment of P100 billion in the Philippines. Chinchua Non-ferrous Metals Corporation and Shanghai Dao Steel Corporation are intending to invest about P1.2 billion. Also, Chingchu Crystal Co. will invest 200 million US dollars in an integrated glass manufacturing facility in Subic. Ambassador Delia Albert, who is concurrently presidential envoy on mineral development, went to the Minerals Congress in Indaba, South Africa to promote investments in the Philippines. Her trip to South Africa also generated interest in the mining industry, with the Minister of Mines in South Africa committing to visit Manila during the Asian Mining Conference in October. With the presidency of the ASEAN Federation of Mining Associations lodged in the president of the Chamber of Mines, the Philippines will host this regional mining event.

Another mining road show was undertaken in Toronto, Canada during the Prospectors' and Developers' Association of Canada 2005 International Convention Trade Show and Investors Exchange. Drawing lessons from Canada's experience of having an economy driven by natural resources without sacrificing environmental concerns, the team was able to sign two memoranda of agreement, one with CDAC, or the association, and specifically agreeing to environmental excellence in exploration or the IPRI guidelines, and another with the Metallurgical Society of America

for technical cooperation and information exchange in pressing for mining practices and standards. The group was also able to meet with various investment and financial institutions, which expressed interest in financing mining projects in the country.

Very recently, upon an invitation by an events organizer in Singapore, the Chamber of Mines, together with the government, presented the Philippine mining policies and the program of activities to revitalize the mining industry. It is significant to note that among the countries in the region, the Philippines had the advantage of taking the lead in placing the mining industry in the country's economic agenda, and of having the resolve to make this policy a reality.

Consolidating gains over the last three months, the Chamber of Mines is now looking at three basic paths towards the revitalization of the industry:

1. Aggressive external promotion of mining opportunities to foreign investors
2. Harmonization of government policy and bureaucracy through the approved mineral action plans. This would involve harmonization of laws, regulations and ordinances at the national and local levels, streamlining of policy overlaps and procedural flaws in the processing and issuance of mining permits.
3. Social preparation of host mining communities and institutionalized advocacy through local dialogues and information, communication and education programs in specific areas

So with that, you will note that there is aggressive activity being undertaken by the Chamber of Mines together with the government in pursuing the revitalization of the mining industry, and this offers an unparalleled opportunity to strengthen the economy, considering the sorry state of our financial problems as well as poverty in the countryside.

With this resurgence, however, comes the great responsibility to avoid and correct the problems of the past and to put in place mechanisms that, over the long term, will ensure that benefits are clearly and equitably

shared by all stakeholders and address the social, economic and environmental needs of all the citizens, including the most disadvantaged. This is where the roundtable discussion on bioremediation of mining waste will come in.

Our mining companies surely would benefit from this roundtable discussion and will collaborate with the science community to pursue a proper and scientific way of remediating waste from the activity of mining.

With that, thank you for inviting us in the Chamber of Mines, and I promise you that in the roundtable discussion, our company representatives will be able to tell you the current concerns of each company in terms of waste management in its particular operations.

MINE WASTE AND MILL TAILINGS MANAGEMENT

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Before we proceed to discuss the topic “Mining Waste Management and Mill Tailings Management.”, let me define some terms:

1. Mine Waste – means solid and/or rock materials from the surface or underground mining operations with no present economic value to the generator of the same.
2. Mill Tailings – means materials whether solid, liquid or both, segregated from the ores during concentration/milling operations, and which have no economic value to the generator of the same.
3. Mine Waste Dump – refers to a designated place where mine wastes are accumulated and/or collected.
4. Tailings Ponds – refers to the structures for impounding mill tailings.

In the Philippines, there is actually no detailed and specific regulatory legislation relating to tailings management. Its implementation is embodied in the following:

- Republic Act No. 7942, known as the Philippine Mining Act of 1995, as implemented by DENR Administrative Order No. 96-40.
- Presidential Decree No. 984, known as the National Pollution Control Decree of 1976.
- Presidential Decree No. 1152, the Philippine Environment Code.

STATUTORY REGULATIONS

Tailings management operates within a mutually enforcing legislative framework and can be considered under three main headings:

- a. pollution prevention legislation;
- b. general environmental framework legislation; and
- c. resource conservation legislation.

Pollution Prevention Legislation

One of the earliest legislation that addresses pollution control and/or abatement is Republic Act No. 3931 of 1964, known as the Pollution Control Law. This was later revised by Presidential Decree No. 984 of 1976, known as the National Pollution Control Decree. Under this law, pollution prevention was administered by the then National Pollution Control Commission (NPCC), including authorization and permitting procedures.

While the legislation relating to pollution control does not directly refer to tailings disposal systems, the past and current practice is to include tailings disposal under the “wastewater treatment facilities” category. With the passing of Republic Act No. 8749, known as the Philippine Clean Air Act of 1999, which converted the Environmental Management Bureau (EMB) of the DENR from a staff bureau to a line bureau, the institutional mandates and machinery to effect pollution control policy is lodged in the said agency.

Under PD 984, before an inland tailings disposal system can be constructed and utilized, the proponent or company has to obtain a permit called “Authority to Construct Certificate”. Prior to utilization of the tailings dam, another permit must be secured, this time a “Permit to Operate”.

To further rationalize and harmonize the management of mine waste and mill tailings storage structures, DENR Administrative Order No. 2000-101 was promulgated. The permit regulations governing mine wastes and mill tailings storage structures are now covered by a current and valid Environmental Compliance Certificate (ECC) issued by the DENR and an Authority To Construct and Operate (ACO) issued by the concerned EMB-Regional Office of the DENR.

On August 25, 2004, Department Administrative Order No. 2004-25 was passed, which amended Chapter V, Article I of the Implementing Rules and Regulations of PD 984 by deleting the Authority to Construct and conversion of Permit to Operate to Discharge Permit for Water Pollution

Source/Control Facilities. Under this DAO, an application for a Discharge Permit shall be filed by the owners or operators of facilities that discharge regulated effluents with the EMB.

Under the existing rules and regulations, before the EMB can issue permits to all mining applicants/permittees that will construct and/or operate mine wastes and mill tailings storage facilities shall secure a clearance from the MGB or its Regional Offices without prejudice to applied permits from the concerned DENR agency/ies.

General Environmental Framework Legislation

The very first reference as to how mine wastes and mill tailings should be managed is seen from one of the general environmental framework legislations, i.e., Presidential Decree No. 1152 or the Philippine Environment Code.

Environmental legislation usually covers Environmental Impact Assessment (EIA) and forms an integral part of project planning, construction and operation. The EIA is provided for under Presidential Decree No. 1586, which establishes the Philippine Environmental Impact Statement System.

For all major mining/quarrying projects, one of the mandatory requirements is the issuance of an “Environmental Compliance Certificate (ECC)” by the DENR Secretary based on the EIS submission. This document is a fundamental requirement prior to the development and utilization stages of mining operation, including mineral processing and mill tailings disposal management.

In the issuance of an ECC, the operating conditions attached to all mining projects focus on the stability, engineering integrity and risks to third parties of the tailings dams/ponds. These conditions are now incorporated in ECCs issued to mining projects upon the recommendation of the Mines and Geosciences Bureau (MGB).

Resource Conservation Legislation

The mining industry in the Philippines is governed by Republic Act No. 7942, the Philippine Mining Act of 1995, and Department Administrative Order No. 96-40, its revised implementing rules and regulations. These

are considered as the primary investment vehicle in the country's effort to revitalize the mining industry. Enshrined are the principles of sustainable development and a new regime of mining that is both pro-people and pro-environment in sustaining wealth creation and an improved quality of life.

In the case of tailings dam or mine waste dump construction and operation, the Act and its IRR have set several environmental protection requirements including:

- Application of mining, civil, hydrological and geo-technical engineering technologies to ensure the long-term safety and stability of such structures including embankments, stored residues and ancillary structures during operations;
- Control/abatement of pollution sources;
- Financial and technical competence to undertake environmental management;
- Emergency preparedness through risk assessment;
- After-use consideration;
- Incentives for pollution control infrastructures and devices;
- Decommissioning and rehabilitation; and
- Post decommissioning and rehabilitation monitoring and surveillance.

An important provision of DAO 96-40 is the requirement for mining companies to allocate for initial mine environmental-related capital expenditures (including tailings management systems), an amount that shall approximate 10 percent of the total project cost.

Further, the MGB requires the submission and approval of an "Environmental Protection and Enhancement Program" (EPEP) which provides a description of the expected impact of the mine and sets out the life-of-the mine environmental protection and enhancement strategies based on the best practice in environmental management in mining including mine wastes and tailings dam management. It also includes statements on post-mining land use potential for various kinds of disturbed lands such as mine pits, waste dumps, tailings impoundment structures, and other mine structures.

A financial assurance is required to be lodged and fund mine rehabilitation progressively and in the event of cessation of mining operations and payment of compensation for damage caused by mining operations. It is called the Contingent Liability and Rehabilitation Fund (CLRF), which is the primary mechanism for mine rehabilitation and multi-partite monitoring through the Mine Rehabilitation Fund (MRF) and damage compensation through the Mine Waste and Tailings Fee Reserve Fund (MWTFRF).

The Mine Rehabilitation Fund is composed of the Monitoring Trust Fund (MTF) and the Rehabilitation Cash Fund (RCF). The MTF shall be in cash and in an amount not less than fifty thousand pesos (P50,000.00), replenishable every month, to cover maintenance and operating expenses for transportation and travel, laboratory analysis, supplies and materials, communication, etc. incurred by the monitoring team. The RCF is established to implement rehabilitation activities under the EPEP and place an amount equivalent to 10 % of the total amount to implement the EPEP or P5 million, whichever is lower. It shall be replenished annually.

The MWTF is also collected based on the volume of mill tailings and mine waste produced. Mine waste dumped in designated place is charged P0.05 per metric ton while mill tailings impounded in tailings ponds have to pay a corresponding fee of P0.10 per ton. This fee accrues to a reserve fund to be used in case of damage caused by mine pollution. Also, under the new law, mining companies which directly or indirectly allow their tailings to find their way into river systems will be penalized a fine of P50.00 per ton.

As part of the holistic approach in improving the management of mine wastes and mill tailings impounding structures, DENR Memorandum Order No. 99-32 was passed on November 24, 1999. This is called the “Policy Guidelines and Standards for Mine Wastes and Tailings Management”.

The primary objective of these guidelines and standards is to effectively manage mine waste and mill tailings in environmentally acceptable health, safety, social and cultural concerns. It shall govern all mine wastes and mill tailings management within the territory and exclusive economic zone of the Republic of the Philippines.

The specific provisions of these guidelines and standards include site selection, design, construction, operation and rehabilitation/decommissioning of mine waste and mill tailings storage facilities. It also discusses conditions for the use of deep sea tailings placement, which can be allowed only when other tailings disposal and management options are not environmentally, socially, technically and economically feasible or when a deep sea tailings placement system exhibits the least environmental and social risk.

CONCLUSION

The various concepts of mine waste and tailings disposal have changed at a very rapid pace in the recent past due in part to advancing technology and the emergence of different regulatory concerns.

Historically, not only in the Philippines but throughout the world, tailings disposal begun as the practice of dumping tailings into nearby streams, and progressed to empirical design of impoundments by mine operators based on less than satisfactory principles of trial and error. Now, however, the planning and design of tailings embankment have gone beyond the principles of geotechnical engineering ordinarily used in the context of design practices for water retention dams.

Reclamation is a concept relatively new to the practice of tailings disposal, especially in the Philippines. Under the new mining law, a Final Mine Rehabilitation/Decommissioning Plan should be submitted five (5) years prior to mine closure, detailing the company's expected post mining land use, including the estimated cost of rehabilitation and the ten-year maintenance and monitoring period. This includes rehabilitation/decommissioning of tailings impoundment areas. Tailings management must continue until such time as the deposited tailings are assured to be permanently stable and environmentally safe.

It is hoped that with the introduction of new standards as well as the entry of other major players of the mining industry, tailings dam failures in the Philippines will be a thing of the past.

ENVIRONMENTAL INITIATIVES OF THE MINERALS INDUSTRY

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This paper presents the National Science and Technology Plan (NSTP) of the Department of Science and Technology (DOST), and of the Philippine Council for Industry and Energy Research and Development (PCIERD) on the mining and minerals sector. The presentation highlights the environmental initiatives of the mining industry and updates on the mineral action plan. It also presents the environmental initiatives, plans and programs of the government for the mineral industry.

The National Science and Technology Plan (NSTP) defines the direction of science and technology development in the Philippines for the next 18 years and the foundation of future economic development. Specifically, it contains the DOST Medium-term Research and Development programs to address pressing national problems, improve productivity in the production sector, develop new technologies and products towards global competitiveness and develop competence in pioneering or new areas.

The priorities under the mining and mineral sector in the NSTP include mineral resources processing, groundwater studies, geophysical exploration, and other earth science-related activities. They also include environmental concerns such as in remediation and rehabilitation technologies, restoration of environmental ecosystems, wastewater treatment technologies and handling of hazardous wastes. The DOST is involved with the natural disaster mitigation program. Also included in the plan is material sciences engineering, wherein one of the goals is to upgrade the mineral values.

As a sectoral planning Council of the DOST, PCIERD conducts and supports R&D projects, institution building, manpower development and

scholarship, seminars and conferences, technology transfer and policy directions. The Mining and Minerals sector is one of the nine sectors being supported by PCIERD. Under the PCIERD sectoral plan 2004 to 2010 for the sector are the development of exploration models, techniques for mining operations to ensure safety and optimum mining recovery, beneficiation technologies to upgrade low grade ores and ensure optimum recovery of primary and secondary minerals from their ores, and technologies for the utilization of local raw materials and production of value-added mineral products.

At present, the PCIERD sees the need to prioritize gold and copper needs and search for blind deposits for industrial minerals, coal, and mineral value adding activities. The way to go to achieve these is through the conduct of new exploration and technological breakthroughs for metallic and non-metallic minerals.

With regard to the environment, the focus is more on the R&D programs of the minerals industry.

With the Environmental Protection and Enhancement Program (EPEP), ten percent of the total cost of the mining project will be devoted to R&D activities. When the proposed practices are in place, a research program to improve the impact control area like rehabilitation technology shall be required. This is where the group of bioremediation can come in. Of course, there are other activities of mining companies in their areas like social development programs. The monitoring of these activities is done by the Department of Environment and Natural Resources (DENR) to look into the sustainability of the environmental programs. There is the liability and rehabilitation fund, wherein ten percent of the total project can be used for R & D funds. This is where R & D funds will come in. Ten percent of that, or roughly five million pesos, is allocated for R&D projects, and can also be used for the rehabilitation of the operations of the mining company.

Another initiative of the mining companies is to adopt a mountain, or adopt a mining forest. One of the problems is that mining companies only plant trees for the rehabilitation of the land area. Most of them do not look into the species of trees to be planted for bioremediation

technology applications. As per previous evaluation, most of the mining companies only plant those that are endemic to the localities of the mining area.

One focus of the mining industry, which is part of the mineral action plan is to remediate abandoned and idle mines. But one of the problems of the technical working group is how to generate funds for this activity. Another significant mineral action plan is to protect the environment, and institute mitigation and progressive rehabilitation measures.

The DOST Research and Development for the mining and minerals sector is tied to the ten-point agenda of the President, wherein mining is one of the focal activities. The industry presents opportunities for employment in the country, and therefore contributes to national development. However, in supporting the minerals industry, the national policy agenda is for a sustainable environment in the conduct of mining activities in the Philippines.

**Presented the paper

OVERVIEW OF BIOREMEDIATION TECHNOLOGIES FOR MINE INDUSTRY

ASUNCION K. RAYMUNDO

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Workshop Coordinator, Professor, University of the Philippines Los
Baños

I'm so glad that we finally have this roundtable discussion. We have been preparing for this activity for a long time now, but kept on postponing it to accommodate the Chamber of Mines because they are the main stakeholders for this activity.

Let me give you a brief background on this activity. It started with the initiative of NAST, as our President discussed a while ago. NAST is mandated to recognize outstanding achievements in science and technology and advise the President and the Cabinet on matters related to science and technology.

One of the pressing issues/problems identified by NAST was the presence of toxic and hazardous wastes in various hot spots in the country. There were reports of severe effects on health and the environment, and we recognize the opportunity to use scientific expertise to benefit our community. Thus, NAST came up with this task force, and we were mandated to design a research program on bioremediation, develop capabilities of local scientists, create a pool of expertise to tackle problems of toxic and hazardous waste, and develop technologies for the remediation of toxic and hazardous waste (THW).

In answer to this mandate, we came up with a workshop on remediation as a whole. Topics discussed during that time were environmental impact on areas affected by hazardous waste, medical and health implications of toxic and hazardous waste, and some strategies for remediation.

After that workshop, I called on different stakeholders and the academe, and formed a remediation research team. Faculty from UP Los Baños, UP Diliman, Ateneo de Manila, DENR, DOH and some from private

industry answered my call. From there on, we conducted a series of meetings and agreed that our approach would be bioremediation, defined as the use of microorganisms and plants to detoxify and degrade environmental contaminants.

The goal then is to detoxify pollutants to concentrations that are either undetectable, or if detectable, to limits established as safe or acceptable by regulatory agencies. At that time, there was talk of a \$50 million fund for the remediation of toxic and hazardous waste in US bases. Thus, we visited Clark and Subic bases and discussed with officials of DENR, prepared proposals and submitted them. PCIERD actually told us that they are willing to fund it. The proposal consisted of the bioremediation of toxic and hazardous waste-contaminated areas of the Philippines, with focus on the former military bases in Clark and Subic, and included these different projects: benchmarking of organic and inorganic contaminants, phytoremediation of contaminated areas, microbial remediation, with focus on PCB, which is a problem in the bases, ecological functions of terrestrial and aquatic biological systems, and the bioremediation of areas polluted with THW.

But we found out that there were many issues attached to this. There were political issues. Nowhere could we find the \$50 million funds that were touted about. It was difficult. No industry was interested to partner with us. Who would want to fund the remediation of the US bases? We were not able to get any funding.

So we shifted gears and focused on the wastes of the mining industry. We were made aware of the presence of abandoned mines which are unusable. With the mediation of UNESCO Commissioner Leonarda Camacho, who is with us today, we were able to talk to Secretary Neri and his representative, Mr. Rudy Cruz. We were also able to talk with the President of the Chamber of Mines, Mr. Philip Romualdez. Mr. Romualdez was very enthusiastic about bioremediation. But he said that we have to know what we are dealing with, make a visit and do analysis.

Our initial activity then was the reconnaissance visit to a mine operations site in Benguet, sampling their wastewater and sludge. This was supported by Benguet Mines. The results we got made us realize that the technology

that we are developing is not applicable to their mines because our results were based on samples obtained from Marinduque wastewater. Thus, there is a need for an infrastructure which can serve as an information and communication management decision-making tool to determine what technology to apply for certain mines. So we need to generate and evaluate baseline information on the composition of the wastewater and sludge of the mining industry. We actually submitted proposals to Mr. Romualdez of the Chamber of Mines.

But I understand that each mining company has its own composition analysis. So if they could try to share it with us, or the Chamber of Mines could provide us with this information, we will be guided accordingly on the technology appropriate for a certain mine site.

We would therefore like to present the bioremediation-based technologies that can be developed for the management of waste from the mining industry. We wish to harness the diverse indigenous organisms which can be utilized for treatment and rehabilitation in the mining industry. And thus, we from the scientific community are more than willing to assist the industry in this environmental challenge. But we have to emphasize that the technologies we are developing are for the mining industry, so we have to develop them with the industry. We need applied knowledge from the stakeholders. We need to be guided by them, how to go about it, and what, perhaps are the important points to consider in our research.

Bioremediation-based Technologies for the Management of Wastes from the Mining Industry

Goal:

- To degrade pollutants to concentration that are either undetectable or if detectable, to concentrations below the limits established as safe or acceptable by regulatory agencies.

For the destruction of chemicals:

- In soils in ground water
- In wastewater

- In sludge
- In industrial waste systems
- In gases
 - *Widespread;*
 - *Represents health or ecological hazards*

Chemical classes & their susceptibility to bioremediation

Chemical class	Examples	Biodegradability
Aromatic HC	Benzene, toluene	Aerobic/anaerobic
Ketones & esters	Acetone, MEK	Aerobic/anaerobic
Petroleum HC	Fuel oil	Aerobic
Chlorinated solvents	TCE, PCE	Aerobic/anaerobic
Polyaromatic HC	Anthracene, creosote	Aerobic
PCB's	Arochlors	Not readily degradable
Organic cyanides		Aerobic
Metals	cadmium	Not degradable; exp'l biosorption
Radioactive mat'ls	Uranium, plutonium	Not biodegradable
Corrosives	Inorg. Acids, caustics	Not biodegradable
Asbestos		Not biodegradable

Interdisciplinary approach:

- Microbiology
- Enzymology
- Ecology
- Geology
- Chemistry
- Botany
- Environmental toxicology
- Environmental engineering

What the proposal offers:

- Phytoremediation and mycorrhizal technologies for the bioremediation of abandoned and/or active sites (field trials)
- An information infrastructure which could serve as a communication and management/decision-making tool for selecting appropriate site-specific bioremediation technologies
- An opportunity to invest in home-grown bioremediation R&D for eventual pilot scale and application

Rationale:

- The revitalization of the Philippine mining industry poses new opportunities and challenges
- Sustainable development focusing on environmental protection -a major challenge
- Treatment of mining effluents and rehabilitation of contaminated sites are primary considerations for environmental management in the mining industry
- The harnessing of indigenous biodiversity through bioremediation offers a good opportunity for treatment and rehabilitation in the mining industry.
- The scientific community offers help/assistance to the mining industry in the environmental challenges that it is now facing

Proposed Research Program

○ Project 1

Field test application of phytoremediation and mycorrhiza technologies for the rehabilitation on contaminated sites.

Expected Output:

- Revegetated/rehabilitated mine sites
- Technical report recommending indigenous plants and mycorrhiza/plant interactions for specific metal pollutants

○ Project 2

Evaluation and generation of baseline information for assessing and recommending site-specific bioremediation technologies

Expected Output:

- Information infrastructure for each abandoned/ active mine site
- Analysis of metal contents of soil, water and vegetation in key areas of the target site
- Menu of appropriate bioremediation technologies for the site
- Catalogue of novel biodiversity (plants and microorganism) which may have potential use as bioremediation agents

○ Project 3

Research and development of potential bioremediation technologies for eventual pilot-scale Testing

- Sub-project 3.1
Phytoremediation technology
- Sub-project 3.2
Biogenic hydrogen sulfide precipitation for the selective recovery of metals from mining effluents
- Sub-Project 3.3
Exopolysaccharide/malunggay seed extract for the flocculation of metals from mining effluents
- Sub-Project 3.4
Electrolytic recovery of metals from mining effluents

Thus we would like to offer the outputs of these researches if ever they are implemented. Then, we hope that the mining industry can invest in these homegrown bioremediation technologies, and help us in the eventual pilot plant scale and application. So, thank you from the bioremediation research team. The team consists of :

- Asuncion K. Raymundo, Ph.D., microbial biotechnologist, IBS, UPLB (Head)
- Nelly S. Aggangan, Ph.D., Forest Biotechnologist, BIOTECH-UPLB
- Nina M. Cadiz, Ph.D., Plant Physiologist, IBS-UPLB
- Nelson M. Pampolina, Ph.D., Forest Environmental Biologist, CFNR-UPLB
- Merab Antone Chan, Ph.D., Aquatic Biologist, Ateneo de Manila
- James Villanueva, Ph.D., Biochemist, UP Diliman
- Ma. Victoria P. Migo, Ph.D., Chemist, BIOTECH-UPLB
- Lorele C. Trinidad, Ph.D., Microbiologist, BIOTECH-UPLB
- Catalino Alfara, Ph.D., Chemical Engineer, CEAT-UPLB
- Fidel Rey Nayve, Ph.D., Fermentation Engineer, BIOTECH-UPLB

It's really a good team. We enjoy working with each other. We just need funds to do our job.

SYNTHESIS AND CLOSING REMARKS,

Emil Q. Javier

Vice President (2002-2005), NAST

The scientific community has the obligation to look into the present and peer into the future. What are the big national problems that we face now and will face in the future which have scientific and technological underpinnings? It is our responsibility and obligation to prepare ourselves for such opportunities and problems.

Toxic and hazardous waste in the environment is one such national issue. Whether we like it or not, it goes with the kind of civilization that we have, especially with more and more people in the planet. And so the immediate challenge idea is, how do you eliminate or abate the production of toxic and hazardous waste in the industries and sectors that produce them? First of all, let us make sure we do not produce them. But if we cannot help producing toxic and hazardous waste, then what do we do after they are released into the environment? And if it is unfortunate enough for it to be released into the environment, what do we do to recover the toxic wastes, degrade them, and decontaminate the environment?

Along these lines, the National Academy of Science and Technology has seen the need to organize a Toxic and Hazardous Waste Task Force among our scientists.. This Task Force, along with the Bioremediation Research Team which Academician Raymundo also chairs, has been actively seeking ways to deal with the problem of toxic and hazardous wastes in the environment. One of the areas in which it has decided to concentrate is mining wastes and abandoned mines which are no longer productive, and yet continue to pose a serious threat. It has conducted a series of meetings with government officials, went on fact-finding missions, and initiated sampling of affected areas.

We are encouraged that the national government, the mining companies, the local governments and the communities themselves are highly sensitized to the environmental problem that the mining industry and other sectors producing and using hazardous chemicals will bring about, together with the benefits they were designed to generate. We have to anticipate them, localize/contain the problems, and apply modern science and technology to mitigate their consequences.

ACKNOWLEDGMENTS

Department of Science and Technology, Philippine Council for Industry and Energy Research and Development for co-sponsoring the Round Table Discussion (RTD) on Bioremediation for Mining Industry

NAST Toxic and Hazardous Waste (THW) Disposal Committee, Acd. Asuncion K. Raymundo – Chair, Acd. Emil Q. Javier, Acd. Jose Q. Juliano, Acd. Apolinario T. Nazarea and Acd. Ruben L. Villareal for facilitating the RTD

Bioremediation Research Team: Dr. Asuncion K. Raymundo – Chair, Dr. Nina M. Cadiz, Dr. Veronica Migo, Dr. Loreli Trinidad, Dr. Phillip Rey Nayve, Dr. Ronald Navarro, Dr. Nelson Pampolina, Dr. Nellie Aggangan Dr. James Villanueva and Mr. Edwin N. Camaya for their efforts in coordinating the workshop

J.C. Raguini and R. Raterta of the Department of Science and Technology, Philippine Council for Industry and Energy Research and Development

NAST Secretariat: Ms. Luningning E. Samarita, Ms. Rowena V. Briones and Mr. Aristotle P. Carandang for their assistance during the THW workshop

Scientists and representatives of academic and other institutions, stakeholders from the Mining Industry, Ms. Leonarda Camacho, Dr. Walter Brown and Congressman Edmundo Reyes for their participation and contribution to the output of the seminar workshop