ADDRESSING THE PROBLEMS AND SOLUTIONS OF ENVIRONMENTAL POLLUTION THROUGH BIOREMEDIATION

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ADDRESSING THE PROBLEMS AND SOLUTIONS OF ENVIRONMENTAL POLLUTION THROUGH BIOREMEDIATION

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Cover photo:
A mined-out area in Mogpog, Marinduque through the years, site of a bioremediation research project. Courtesy of Dr. Nina M. Cadiz, Institute of Biological Sciences, University of the Philippines Los Baños.

DISCLAIMER

The findings, interpretations, and conclusions made by the author do not necessarily reflect the views of the National Academy of Science and Technology (Philippines).

PREFACE

This monograph contains the proceedings of the First National Bioremediation Conference held on October 26-27, 2010 at the Traders Hotel in Pasay City, Philippines. The conference was a successful gathering of almost 200 participants from diverse and interested groups that shared their experiences and challenges in the field of bioremediation. People from the academe, who have been into innovative research by harnessing biodiversity in providing solutions for environmental rehabilitation and wastewater treatment, were in attendance. There were also participants from the industry like mining, leather and jewelry who affirmed their concern for the environment and who shared their experiences with regards to the application of bioremediation technologies. Some government officials, likewise, presented policy approaches towards integrating bioremediation technology in efforts to maintain a safer environment for their constituents.

With 11 plenary sessions, 13 oral and 24 poster papers covering various aspects of bioremediation, the conference provided an opportunity for academe, industry, government and other sectors to interact and learn from each other. Overview of cases where hazardous wastes have affected the environment and how practical bioremediation technologies have been applied were presented. Practical and interesting tools for identifying organisms (plants and microorganisms) with new or improved bioremediation capabilities, as well as practical bioremediation technologies developed abroad and which could be adapted to Philippine conditions, were also presented. Information as to how the government is coping with the management of hazardous wastes and in which bioremediation could help were shared. The addition of sociological and health/toxicological dimensions in the presentations reminded the participants of the position of bioremediation in the stakeholder approach in solving environmental problems.

I hope that this monograph will serve as a basis for future bioremediation efforts and as a reference for new researchers in this area.

ARaymundo

ASUNCION K. RAYMUNDO
Chair, Organizing Committee
Academician, National Academy of Science and Technology

FOREWORD

Pollution of the environment especially of persistent organic chemicals and heavy metals is a growing national concern. The obvious remedy is prevention of the pollution in the first place through public awareness of the health hazards; through legislation and effective enforcement, and swift, heavy penalties for polluters.

The National Academy of Science and Technology in the exercise of its advisory mandate has seen it fit to assemble the country's scientific expertise to look into this growing concern and determine how areas that have been polluted can be rehabilitated and nursed back to health. They were tasked to inquire particularly on biological methods to restore degraded sites to complement physical and chemical methods.

These proceedings are the outcomes of the conference organized by the Bioremediation Task Force chaired by Academician Asuncion K. Raymundo. We hope these will catalyze further efforts in developing technologies to contain hazardous materials in the environment.

E. Q. Javier

Emil Q. Javier
President
National Academy of Science and Technology, Philippines

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WELCOME REMARKS

For many years now, pollution - on air, water, and land - has been one of our leading problems. Recently, it has become more serious because of rapid population growth, the aim for industrialization, as well as the production of more consumer products with hazardous chemicals. Unfortunately, there has been little action from the government or the private sector to a concern that poses grave hazards to our health and the environment.

The Philippine's National Academy of Science and Technology (NAST), which counts among its members many of the country's leading scientists, and which advises the government and the public on scientific matters, has tried to anticipate developments in this profound, extensive public concern, before the problem becomes even more serious. Thus, a few years ago, NAST created a bioremediation team composed of young, accomplished, and promising scientists in disciplines, which interface with or are involved in bioremediation. The team is led by Academician Asuncion K. Raymundo, a leading light in her field of microbiology as well as an outstanding administrator for decades now. The group has already published results of its research projects, organized workshops, and networked with officials and groups involved in the same or related fields. Upon its recommendation, the NAST is organizing a conference together with the University of the Philippines Los Baños (UPLB). The Academy hopes that it will be the beginning of a multi-sectoral, broad-response to a problem whose implications are deep, wide-ranging, and can extend far into the future.

We hope the participants and the different sectors of society learn more about bioremediation concerns because, in the end, this knowledge will be the key to the solution of many of our environmental problems. If this conference does its part in disseminating environmental awareness to key sectors of our society, it will have succeeded. For its part, the NAST will continue to do its role of informing our government and our people on how science and technology can contribute to a progressive Philippines.

E Q. Javier

Acd. EMIL Q. JAVIER, Ph.D.
President
National Academy of Science and Technology

MESSAGE

The Department of Science and Technology is pleased to welcome everyone to the First National Conference on Bioremediation. The event is highly important especially with the rising global concern to take care of the environment. With its theme "Addressing the Problems and Solutions of Environmental Pollution through Bioremediation," the conference aims to present interdisciplinary approaches that will help in the rehabilitation of the environment. More importantly, the event will focus on locally available solutions by featuring proposals from the Philippines' own pool of experts. Everyone should take full advantage of this conference by coming up with concrete plans of action for technology commercialization and sustainable development.

We hope that by initiating this conference, more sectors will join us in our continuing efforts to protect the environment through bioremediation.
Mabuhay!

MARIO G. MONTEJO
Secretary
Department of Science and Technology,
Republic of the Philippines

MESSAGE

The state of the Philippine environment is undeniably worsening. The rapid increase in population, urbanization, and industrialization leads to the accumulation of recalcitrant wastes and threatens the viability of our land and water resources. Seeing that there is low spending priority for the environment, particularly for sanitation and sewage, I fully agree that it is not enough that we stay abreast with new waste treatment technologies. We must also make every effort to develop and employ natural, eco-friendly, and cost-effective solutions to clean our environment.

I wish to congratulate the National Academy of Science and Technology and the University of the Philippines Los Baños Bioremediation Team for coming up with the First National Conference on Bioremediation with the theme "Addressing the Problems and Solutions of Environmental Pollution through Bioremediation". This gathering of scientists and institutions highlights the need for a more profound research and collaboration on bioremediation technologies and approaches.

May this conference be a source of inspiration to everyone as each commits himself to rehabilitate our ailing environment. Let us all work together to win the battle of our time with due regard to the progress and success of future generations.

Again, congratulations. Mabuhay kayo!

LUIS REY I. VELASCO
Chancellor
University of the Philippines
Los Baños

MESSAGE

I congratulate the Philippine Council for Advanced Science and Technology Research and Development, National Academy of Science and Technology and the University of the Philippines Los Baños for addressing the problems of and giving solutions to environmental pollution through the holding of the "First National Conference on Bioremediation".

Pollution is a complex problem that is usually associated with urbanization and industrialization coupled with rapid increase in population and agricultural intensification. Various forms of effluents coming from raw sewage, detergents, fertilizer, heavy metals, chemical products, oil and even solid wastes have contributed significantly to pollution of freshwater bodies such as rivers and lakes as well as coastal and marine areas. The net effect is the deterioration of water quality which impact tremendously on biodiversity and overall productivity of these ecosystems including human health. This range of impacts translates into environmental costs and economic losses estimated at PhP67 Billion annually (WEPA).

Interest in bioremediation has intensified in recent years as mankind strives to find sustainable ways to arrest the worsening environmental pollution in all sorts of water bodies. The use of plant enzymes and microorganisms is viewed as a sustainable approach to restore the productivity and ecological condition of aquatic ecosystems. Let it be emphasized, however, that caution must be observed in the use of exotic species because this is highly regulated under various international conventions, laws and regulations for the conservation of biological diversity. This implies prioritizing indigenous species to avoid the endless cycle of introducing new species to control another exotic species.

A strong research is the backbone of any strong regulatory system. The logical and practical approach to address environmental pollution is to make use of multi-disciplinary approach which combines advanced science and technology with environment, social and economic perspectives. This appears to be the best strategy to guide the preparation of the National Agenda on Bioremediation.

I commit the full support of the Department in this kind of collaborative endeavour. I am optimistic that this conference will not only enhance awareness but will also facilitate integration of recent research developments, promote transfer of technology and encourage innovative application of bioremediation in accordance with the DENR's vision for a healthy and productive environment.

More power!

RAMON J.P. PAJE, CESO I
Secretary
Department of Environment and Natural Resources
Ecosystems Research and Development Bureau

INTRODUCTORY REMARKS

When the NAST Bioremediation Team was first constituted a few years ago, we had hoped to blaze a new trail in the fight against pollution. The problem of pollution dates back a long a time ago, although detailed knowledge of its environmental and health costs and measures to contain them, would only come much later. On the other hand, managing hazardous waste, particularly through bioremediation which is a cheaper and sustainable approach, is still in its infancy in the country. We were, in this sense, following a new path, although many previous bodies had already been appointed to look into the problem of pollution. What lent a sense of urgency to the use of this approach is the series of environmental disasters involving hazardous materials, and the health problems of the people affected.

Since then, we have organized a series of round table discussions, in addition to several research efforts, meetings with other researchers, concerned officials and industry leaders as well as plant visits, site inspections, publications, posters and paper presentations. This Conference, we hope, will serve to bring together leaders of various sectors concerned with the problem of pollution and will consider bioremediation as a possible mitigating measure. It will also function as a venue to unify efforts against pollution and hazardous waste, with the scientific community and the academe becoming active partners of the different stakeholders.

We began our work in the NAST Bioremediation Team with high hopes, and similarly I have high hopes for this Conference. The problem is large, broad-based and affects so many, and it will not be easy dealing with it. With the cooperation of the government and of various stakeholders, I am sure that this Conference can make a difference.

AKRaymundo

ASUNCION K. RAYMUNDO
Academician, National Academy of Science and Technology;
Chair, Conference Organizing Committee and Bioremediation Team;
Dean and Professor, College of Arts and Sciences, UPLB

THE AUSTRALIAN EXPERIENCE AND A VIEW OF THE CHANGES FROM WANTON DESTRUCTION AND CAN'T CARE LESS TO BEST PRACTICE IN MINE RESTORATION

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Research Fellow, School of Chemistry
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Balik-Scientist, DOST

ABSTRACT

The mining industry in Australia as in most of the highly industrialize d nations endowed with abundant mineral resources has created a major legacy of land degradation. This has been due to the removal of the previously functional vegetation communities and creating unstable and barren waste materials which also produced heavy metal pollution. Attitudes and practices have evolved and moved on and the industry has recognized the need to formulate various prescriptions, with the overall objective of mine closure to prevent or minimize adverse long-term environmental (physical, social and economic) impacts, and to create a stable landform suitable for some agreed subsequent land use. Mine site rehabilitation is defined as the return of a disturbed site to a form and productivity level that conforms to a defined end land use that may not be necessarily the original use.

I will describe a landmark mine closure program to reclaim a highly polluting mining operation and present examples of our work which reflect the changes in mining environmental operations in Australia. In my opinion, because we, as educational institutions in Australia, have produced this large pool of competent students who are aware of environmental stewardship, the educational outputs e.g., skilled students, has also allowed the mining industry to significantly improve its performance. This would be a worthwhile scenario to consider in the Philippine context. In realistic terms, government funding agencies as well as current mining operations must be encouraged to contribute to the upskilling of college and university students by supporting research projects through provision of logistic support to

undertake these experiments. We have effectively showed that empirical data generated from these projects are important. Experiments carried out by students under the guidance of competent plant and soil scientists simply provide good evidence of what can and cannot grow on mine wastes. Implementing academic programs of this kind in the Philippines can generate very useful information for the whole industry within a very short span of time (2 - 3 years) which would allow progressive mine restoration to be undertaken.

INTRODUCTION

This review highlights the major shift in processes in the Australian mining industry which left behind large areas of severe degradation of the mined environment to that in which an ethos of developing and evolving practises which would maintain a mining company's social license to operate in the community. Historical mining operations resulted in post mining landscapes impacted on ecosystems functions, which were severely disrupted due to removal of the resident biota, soil forming process as well as the hydrological cycles. Moreover, there was a lack of understanding of the geochemical processes, which created heavy metal pollution due to the leaching of exposed and weathered mineral wastes from the mining operations. Developments in the last 30 years due to community expectations have resulted in legal requirements to develop safe, stable and non-polluting post mining landforms.

IMPACTS OF MINING ON LANDSCAPE

The mining of precious metals and other minerals over the centuries has created landscapes which have been degraded to the point that biological processes are impoverished or drastically reduced in comparison to the previously unexploited state. Mining is often a short-term land use proportional to the size of the ore reserves. However, the absence of appropriate environmental procedures during the mining process can cause major degradation of the surrounding landscapes. The legacy of past mining practices worldwide prior to implementation of legislation to safeguard the environment has produced large areas of wasteland and often chemically toxic and structurally unstable landforms.

Industrialization across the world has driven demand for the discovery and exploitation of mineral resources such that there is widespread disturbance of land surfaces in many countries. Total land disturbance remains relatively small with less than 0.2% of the land surface in USA (Bradshaw and Chadwick, 1980) or India (Dhar and Chakraborty, 2002), 0.01% in China (Wong and Bradshaw, 2002) and 0.05% in Australia (Bell, 2001). Nonetheless, the total surface area impacted in these four large nations amounts to 65 Mha spanning many biogeographical regions. Smaller countries such as Cuba and New Caledonia which have highly mineralized areas rich in nickel and chromium may potentially have up to 5% and 30%, respectively, of their land surfaces impacted by mining activities (Becquer et al., 1995; Berazain, 1995).

In order to access valuable orebodies the immediate impact of mining (on terrestrial ecosystems) is often the removal of whole ecosystems. Large-scale mining operations may also change the hydrological balance through the alteration of river flows and ecology as well as changing water tables through the overuse of water resources or through mine dewatering. Other changes to the landscape are caused by the formation of large waste rock piles and TSFs as well as voids after the extraction process.

Land degradation by mining has been well documented in many parts of the world (UNEP, 2000). Aside from the immediate effects on ecosystems, other impacts include: destruction of adjacent habitats as a result of sediment run-off from mine sites; release of toxic metals and other chemical pollutants by air emissions; acidic mine water and other mine effluents; deposition of dust upon surrounding habitats and creation of potentially unstable landforms. Most of these impacts have been due to the absence of any preventive measure during the life cycle of the mining operation.

Large-scale mining is now required to operate within a legal framework which protects the environmental assets of many countries. Highly industrialized countries such as the USA and Australia have enacted numerous pieces of legislation which regulate the use of land resources and environmental impacts of human activities. The main Act of Parliament created by the Commonwealth of Australia to safeguard the country's natural and environmental resources is the Environment Protection and Biodiversity Conservation Act (Australian Government, 1999). All Australian states and territories have passed stringent legislation which imposes penalties on polluters which can be summarized in the simple phrase, the polluter pays. At least 100 Acts of state and federal parliaments have been implemented which affect the regulatory process with implications for the mining industry in order to improve environmental performance as well as allow financial competitiveness (Bradfield et al., 1996). There has been constant reappraisal of the environmental management process to allow for the developments in new technology, changing economic climate, increased environmental awareness and expectations of the community (Brooks et al., 1996).

IMPACTS OF TAILINGS ON THE ENVIRONMENT - THE INTERNATIONAL SCENARIO

Tailings are the solid waste product after milling of ore and extraction of the target minerals. The milling process involves crushing ore into very fine particles. After separation of the economic mineral through chemical and physical processes, a large proportion of the ore, as residues, is discharged and contained in TSFs. The latter are built as dammed valleys or as free-standing structures like embankment dams. The failure of these structures is recognized as one of the major mining-related risks to the environment. A minor amount of tailings is also discharged into old underground or open cut mine workings. Three-quarters of the environmental damage reported in the mining industry since 1975 have been due to tailings material being released to the surrounding environment, with frequency of major failure being at least once a year (UNEP/ICOLD, 2001). Examples of major tailings spillages include: Marcopper, Marinduque, Philippines where an estimated 2 million m^3 of acidic copper tailings were suddenly released into the Boac and Makulapnit rivers after failure of a concrete plug in a drainage tunnel (UNEP, 1996). In Aználcollar, south-eastern Spain (1998), 3.6 million m^3 of tailings water and 1 million m^3 of residues spilled from the pyrite mine and seriously affected the Agrio and Guadamar rivers as well as 43 km^2 of farmland in which soils were severely polluted with Zn, Pb, Cu, As and Cd. Furthermore, three years after the accident, 50-70% of the acidic soils and 25-30% of the basic soils are still highly polluted with arsenic (Aguilar et al., 2004). Leakages from old tailings facilities have also released sediments from the gold mines of Goldenville, Nova Scotia to create a dispersed tailings field of approximately 2 km^2 after mining had ceased 50 years ago (Wong et al., 1999). These examples show how environmental contamination, due to the continued leaching of chemical pollutants from mining, result in severely degraded areas, e.g. agricultural ecosystems or fish habitats, long after the incidents.

IMPACTS OF TAILINGS ON THE ENVIRONMENT - VICTORIAN SCENARIO, TYPICAL OF AUSTRALIA

Historical gold mining activities in the state of Victoria have left a legacy of arsenic contamination of soils, surface and groundwater with concentrations up to 1.6 % in soils of residential areas of mining towns (DMID, 1991). Because of the elevated levels of arsenic in gold tailings in the Victorian goldfields, exposure to the metalloid has been considered a potential health risk (DHS 1998a; b). A higher incidence of prostate cancer was recorded in men living in rural areas of Victoria, Australia which had elevated soil/water concentrations of arsenic (Hinwood et al., 1999). Remediation of historically degraded areas can therefore, be a very costly endeavour (Richards et al., 1996; Brooks, 1997).

Development of management strategies for the safe containment of mine tailings has progressed significantly over the last few years. Options are being sought for the practical, long-term maintenance of TSFs after mine closure. Mining companies, government regulators and the community all recognize continual maintenance of TSFs is unrealistic and expensive. The adoption of best practice environmental management procedures has become an integral aspect of the mine planning and operation procedure. Thus, minimizing the risk of long-term environmental impacts (Environment Australia, 1995b).

LARGE VOLUME WASTES WITH PARTICULAR REFERENCE TO GOLD MINING

Australia is the third largest producer of gold in the world after South Africa and the United States of America. Export earnings from the local gold mining industry exceeds A$5,500 million (ABARE, 2004). Owing to high demand since the 1980s as well as technological advances in the metallurgical processes, there has been a boom in the gold mining industry. Many deposits which had previously been considered to be commercially non-viable due to the low grades of ore are now being exploited. In many operations the average gold concentration ranges from 2 - 10 gt^{-1}; consequently, to extract a metric ton of gold, approximately 2 million tons of ore have to be processed. These very large volumes of waste rock and tailings can cause major impacts on the mined landscape.

TSFs are most commonly the largest area on a mine site requiring rehabilitation. These structures are often above-ground and prominent in the landscape. Their long-term stability is dependent upon a capacity to withstand occasional heavy rainfall events which occur in Mediterranean environments such as in western Victoria. Whilst revegetation may not be enforced by legislation, in all but the most arid areas, it is a requirement to stabilize rehabilitated tailings and to render them aesthetically acceptable. A recent review has been published on the performance of reconstructed vegetation communities on TSFs in the semi-arid region of Western Australia (Lacy et al., 2004). It reported how various long-term case studies demonstrated that restored vegetation communities successfully established, matured and reproduced on a range of cover systems placed over tailings which contained sulphides and arsenic forms. The information obtained from these studies can be valuable in the development of sustainable closure strategies in the arid mining environment. Successful post-mining remediation will reduce the risk that a site will continue to be hazardous and be a future source of pollution. Mine rehabilitation and subsequent decommissioning ultimately determines whether what is left behind is a benefit or legacy for future generations (Environment Australia, 2002a).

GOALS OF RESTORATION ECOLOGY

The theoretical framework for restoration of landscapes altered by human activities was developed by various pioneer workers in the 1970s expounding the principles which serve as a template for many remediation programs (Bradshaw and Chadwick, 1980; Williamson and Johnson, 1981). They showed the importance of understanding the ecological factors which influence plant growth. Many books and reviews have subsequently been published that document successful land restoration programs which have followed the procedures proposed by these early workers. Some of the more recent publications include Barnhisel et al. (2000), Perrow and Davy (2002a;b) which address remediation of many types of land degradation. Publications useful to the environmental management process in the Australian mining industry include a series of manuals on best practice in mining (Environment Australia, 2002b) and an important review of the various aspects of mining and the environment (Mulligan, 1996).

The pathway and key processes involved in developing an ecologically based restoration program are summarized in the flow chart envisaged by Bradshaw and Chadwick (Figure 1). The general principles presented by Bradshaw and Chadwick (1980) are applicable to any type of mining waste. In the context of this thesis, the main focus will be on mine tailings.

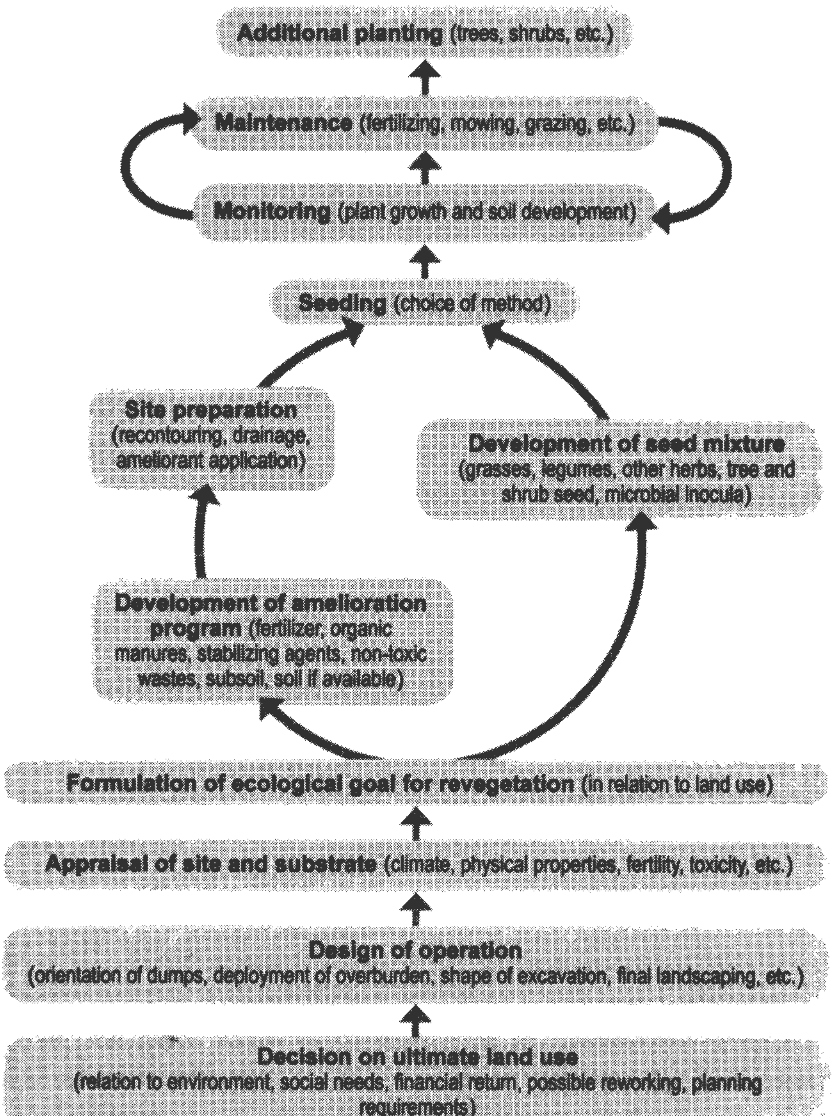

Figure 1. Flow diagram outlining procedures for the development of a successful land restoration strategy (Bradshaw and Chadwick 1980).

Defining End Land use

The initial step in the process of developing a minesite restoration program is to define the desired final land use through consultation with the various stakeholders, e.g. the mining company, resident communities and government regulatory authorities. The mining industry has recognized the need to formulate various prescriptions, with the overall objective of mine closure being to prevent or minimize adverse long-term environmental (physical, social and economic) impacts, and to create a stable landform suitable for some agreed subsequent land use (IIED and WBCSD, 2002). Minesite rehabilitation is defined as "the return of a disturbed site to a form and productivity level that conforms to a defined end land use that may not be necessarily the original use" (Bell, 1996). Open-cast coal mining sites in NSW and Victoria have been successfully returned to pasture and grazing as well as to forestry and recreational and amenity uses, e.g. golf courses (Hannan, 1995).

LANDFORM STABILIZATION

Since mine tailings can easily be moved through the erosional action of wind and water, it is necessary to contain them in stable landforms or structures. The integrity of containment facilities is essential in order to minimize the movement of potentially toxic water or geochemically reactive tailings.

Tailings can be physically stabilized with a thick cover of benign waste rock taken from the mining operation or by forming a compacted impermeable clay layer over the chemically reactive tailings material. A major drawback of this technique is the high costs for earthmoving and creating these highly engineered layers, particularly where suitable materials are scarce (Tordoff et al., 2000).

Chemical stabilization has also been used to create a chemically inert crust over mine waste material. Taylor et al. (1997) describe some recent advances in chemical stabilization of acid mine water which could also be used to stabilize tailings surfaces. Many of these methods are based on reactions which create hardpans such as, allowing acid water to react with lime-based reagents to produce cemented layers with calcite, gypsum and metal hydroxides, and polymer modified clay and grout barriers (e.g. flyash Portland cement mixture) which isolate acid-forming rock from surrounding water. Other chemical stabilizers which are widely used are lignosulphonates, resinous adhesives and sodium silicate chemicals (Lacy et al., 2004). These can only be considered as temporary steps to reduce immediate impacts of wind and water erosion on tailings surfaces and so minimize the release of pollutants into the surrounding environment.

Phytostabilization (the use of vegetation to stabilize surfaces), in particular the use of excluder metallophytes for the *in situ* immobilization of metals and metalloids in polluted soils and environmental mining passives - the legacy of past mining activity (Ginocchio et al., 2004) has been favoured over the previous two techniques. Aside from being relatively more costly, the physical and chemical stabilization techniques are largely incompatible with the formation of soil conditions necessary for sustainable revegetation, particularly by deep-rooted plants.

Self-perpetuating vegetative covers for stabilization of mine wastes have many advantages. Erosion is reduced by plant roots binding the substrate. Evapotranspiration by vegetation reduces the ingress of water through wastes; therefore, decreasing the potential release of soluble toxic metals and metalloids into groundwater, creeks and river systems. A successful revegetation outcome is also more aesthetically acceptable rather than a degraded and derelict mined landscape.

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EVALUATION OF THE HEAVY METALS UPTAKE OF COMPOST FOR POTENTIAL APPLICATION IN TREATING MINE TAILINGS IN THE PHILIPPINES

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ABSTRACT

Soil compost is eyed as a potential metal immobilizing agent because it is rich in microorganisms and organic materials - some of these are known to precipitate out metals into water-insoluble salts. In this study, metal uptake of soil compost was evaluated through *ex-situ* experiment. Soil compost samples were exposed to Ni, Pb, Cd, Al and Cu solutions. The water effluents that passed through the soil compost were then analyzed for the said metals using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Parallel runs were made for pure soil and soil-amended compost. Results showed that the degree of metal uptake generally increases from pure soil to pure soil compost. Insights from this study can be applied to treatment of heavy metals in mine tailings in the Philippines.

Key words: bioremediation, heavy metals uptake, soil, compost, Ni, Pb, Cd, Al, Cu.

INTRODUCTION

Heavy metals are known to be persistent pollutants of the environment (Pruvot et al., 2006). If not properly treated, they can be leached out from the source and contaminate entire ecosystems, starting from groundwater and soil which through the complex food web ultimately affects all living organisms (Roberts and Johnson, 1978). As they cannot be degraded, one of the popular approaches is *in-situ* metal immobilization using soil. Soil is known to sequester metals via physical adsorption and chemical reactions (complexation and precipitation) (Kabata-Pendias, 2000; Pérez-de-Mora et al., 2005). In this study, the effect of adding compost in the metal uptake of soil will be evaluated. Since compost has higher organic content than normal soil, it is expected to have higher number of microorganisms which should increase the efficiency of metal uptake. More specifically: exposure time, temperature and organic content of the soil will be optimized in the study.

METHODOLOGY

All setups were placed in fabricated plastic containers with a down spout at its end. Three matrices containing 100 g of soil (70% minerals, 30% organics), compost (30% minerals, 70% organics) and a mixture of both (50% soil, 50% compost) were contaminated with 10 ppm heavy metal solution of Ni, Al, Pb, Cd and Cu. For each of the matrices, three sub-setups were prepared in terms of varying: (a) Temperature (25°C vs. 12°C), (b) Exposure time (5 minutes vs. 48 hours) and (c) Presence of microorganisms (untreated vs. treated with hydrogen peroxide (H_2O_2)). The sample pre-treatment procedure is illustrated in Figure 1.

To determine the degree of metal uptake, the solutions that passed through the setup were analyzed with Inductively Coupled Plasma - Mass Spectrometry (ICP-MS) at the National Institute of Geological Sciences.

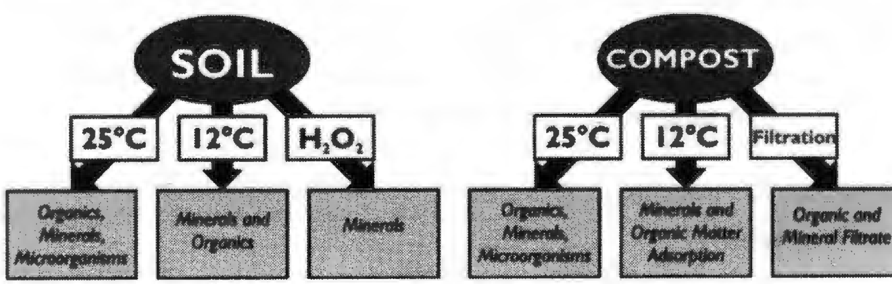

Figure 1. Sample pre-treatment

RESULTS

Of all the studied heavy metals, nickel is the most difficult to immobilize. Its uptake is very dependent on the condition changes, as metal uptake was higher in setups with high organic matter and longer exposure time and at room temperature. Aluminum has excellent uptake in room temperature and at longer exposure periods, however its uptake decreased when the soil was treated with hydrogen peroxide. Cadmium removal gradually increased with increasing organic matter content, longer exposure time and higher room temperature. Lead exhibited the highest decrease in percentages and least dependence on the varying conditions, except for exposure times when immobilization was greater at longer periods. Uptake of copper was significantly higher after two days, but higher organic matter and temperature did not affect the results significantly.

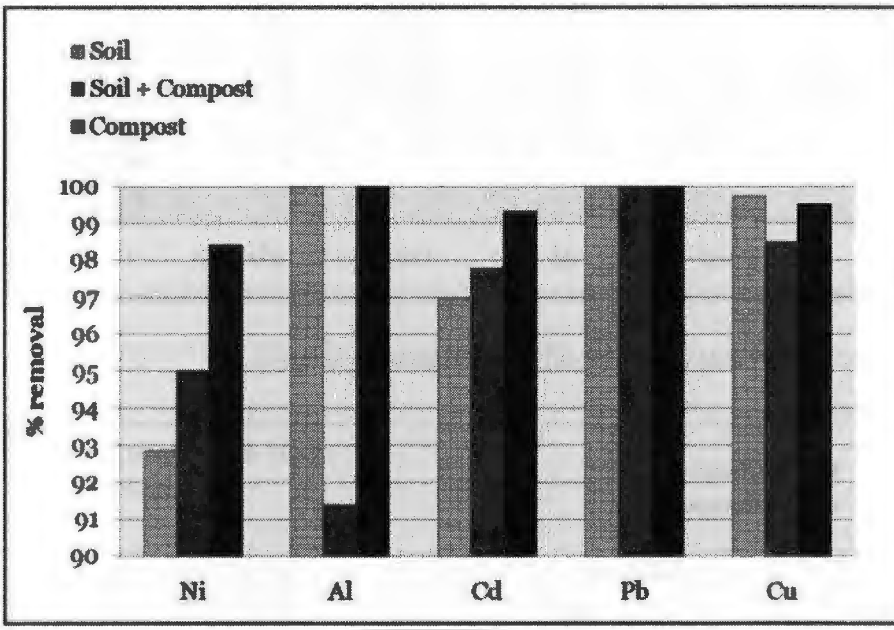

Fig. 2. Heavy metal uptake of soil, compost and soil -compost mixtures

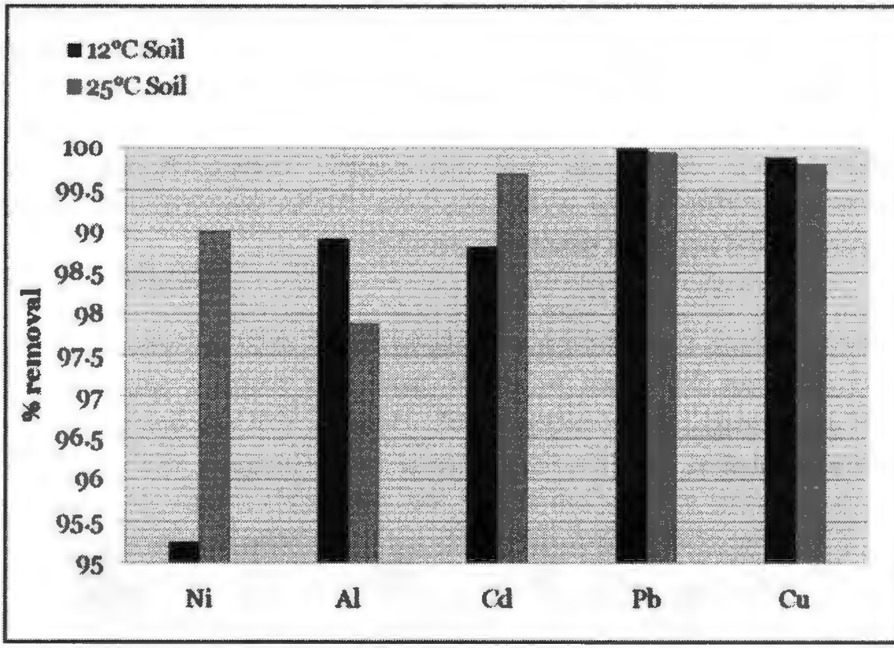

Fig. 3. Heavy metal uptake of soil with variations in temperature

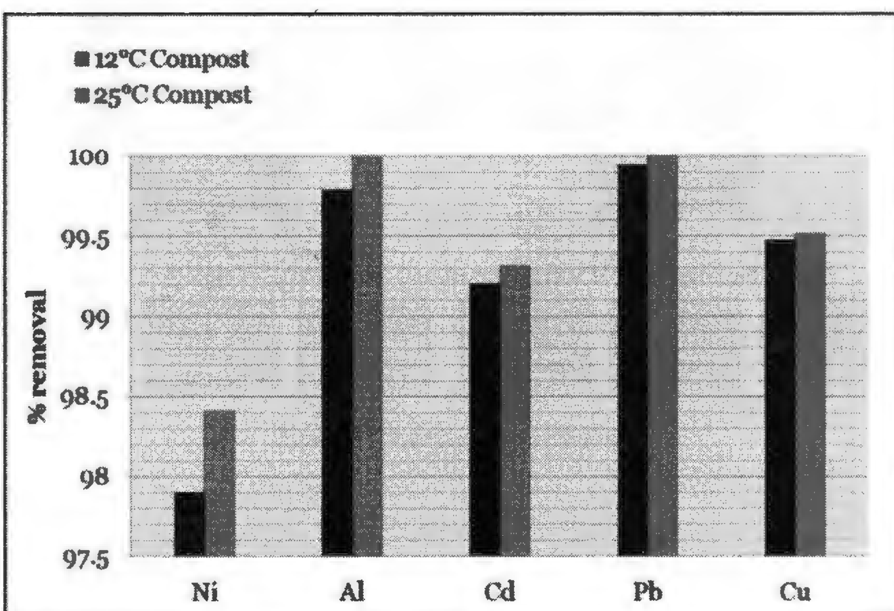

Fig. 4. Heavy metal uptake of compost with variations in temperature

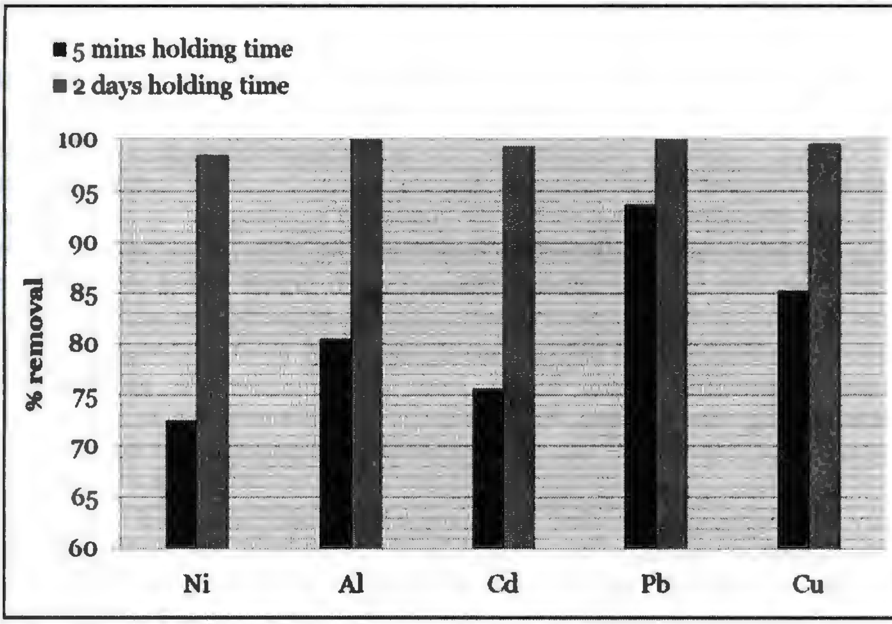

Fig. 5. Heavy metal uptake of compost and soil, with variation in exposure time

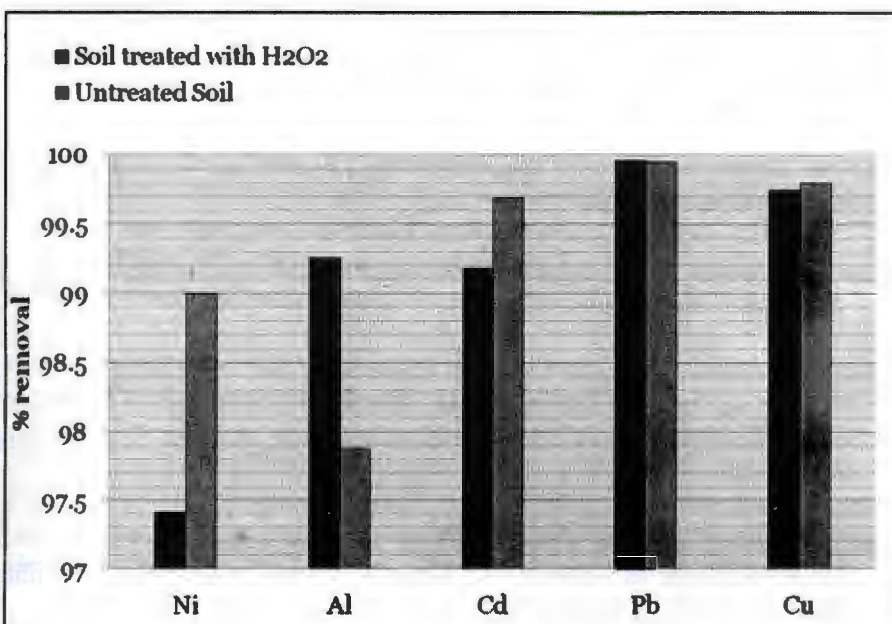

Fig. 6. Heavy metal uptake of untreated soil and soil treated with hydrogen peroxide

DISCUSSION AND CONCLUSION

In this study, compost was generally the best medium for absorption of heavy metals. This observation supports our hypothesis that microorganisms can help in immobilizing metals. It was also apparent that the contact time between the metal solutions and matrix affected the metal uptake. Longer exposure provided more time for the metals to be absorbed by the soil and the compost which resulted in increased percent removal of the metals. In most cases, the setup at room temperature had higher heavy metal uptake than that at a lower temperature. This is probably because at lower temperatures, biological activity slows down and so is the removal of the metal. Removing organic matter from soil decreases its efficiency in immobilizing heavy metals, except for Cu and Pb where the difference was insignificant, and with Al where the effect was the opposite and inconsistent.

All results suggests that microorganisms are involved in metal immobilization indicating that compost is a better immobilizing agent than pure soil. However, due to time constraints, the actual mechanism of immobilization (i.e. complexation, precipitation) was not determined. Future studies on the effect of pH and ion strength of the compost may also help in determining its metal uptake capability (Bradl, 2004). Nonetheless, metal immobilization using compost can be utilized in rehabilitating metal-contaminated mining areas in the country.

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BEST PRACTICES OF PHILEX PADCAL MINE IN ENVIRONMENTAL PROTECTION AND COMMUNITY DEVELOPMENT

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ABSTRACT

Philex Mining Corporation is on its 52nd years of continuous operation. The Sto. Tomas II deposit has produced precious copper, gold and silver and at the same time created jobs and livelihood opportunities, generating foreign exchange and taxes for the country, building communities and protecting the environment.

As a staunch supporter of environmental protection, the company aims for continual improvement of its operation. In September 21, 2002 Philex earned the ISO 14001 certification for its Environmental Management System (EMS), making it the first metal mining in the country to earn such certification. The company implements the following programs watershed management, reforestation, used oil management, tailings pond management, chemical and hazardous materials management, water quality management; slope stabilization projects; noise and air quality monitoring and domestic/ solid waste management, among others.

Philex Mining Corporation has always been an active advocate of community development, recognizing that the operation is dependent on strong partnership with the community. Philex is committed to support and develop its host and neighboring communities under the Social Development and Management Program through the principle of partnership and people empowerment. It has institutionalized its H.E.L.P Programs which stands for Health Care, Education, Livelihood and Program for Infrastructure.

PHILEX BRIEF HISTORY AND BACKGROUNDER

The Sto. Tomas II copper-gold mine of Philex Mining Corporation is located at the southern tip of the Luzon Central Cordilleras about 17 aerial kilometers south-southeast of Baguio City. It is situated in the Municipality of Tuba and Itogon, Province of Benguet. Access from Baguio City is through a 32-km. company-maintained provincial road in an hour's drive. The climate is cool and invigorating with the rains coming mostly between June to October. The company was incorporated in 1955. It is a publicly owned corporation listed with the Philippine Stocks Exchange with over 40,000 stockholders.

As of 2010, the total tenement area of Philex Mining Corporation is 11,923.60 hectares. Developed areas or those affected by the mining operations , which includes the Subsidence and Ore body, Tailings ponds and industrial areas accounts for about 5% of the area. About 50 hectares is allotted for residences, recreation and offices. Since it started its reforestation program, it has successfully reforested more than 2,000 hectares within the mining claims. The rest of the area is in its natural state.

The mine is one of the largest gold producers in the Philippines today. It is also one of the leading exporters of copper in the Far East and has been in operation for 52 years.

The mine products of Philex are gold, copper and silver. It employs the underground block caving method and collects the precious minerals through the flotation process using biodegradable reagents.

It started its production in 1958 with an initial reserve of 18 million metric tons. It was mining then at a rate of 800 tons per day. Through the years, the company developed its mine and mill and as of December 31, 2009, it has milled a total of 337.24 million tons of ore. Today the mine extracts an average of 25,000 metric tons of ore a day.

Prior to the entry of the mines in the area, Padcal used to be a logging concession and a sawmill area. In 1958, while the mine and mill were being developed, the community was also being established. Originally, there were only about seven families and 52 years later, Padcal mine is a bustling community with over 14,000 people of diverse ethnic and cultural background.

Philex envisions to be recognized as a socially responsible Filipino Company striving for excellence in mining, thus it has been pro-active in the field of Corporate Social Responsibility. To achieve this, it has committed to continue:

a) improving its mining operation to be more efficient and cost -effective
b) to expand its business to take hold of emerging opportunities throughout the Philippines to share the benefits from mining

c) to be socially responsible by supporting the communities where we operate and by protecting and enhancing the environment
d) to encourage our employees to use their talents to work competently and safely
e) Aiming for excellence in all our work, we do everything in the best possible way striving to be the best we can be

By focusing on its vision and mission, we are able to improve the stakeholders' lot and contribute to nation building.

BEST PRACTICES OF PHILEX-PADCAL ON ENVIRONMENTAL PROTECTION AND COMMUNITY DEVELOPMENT: AN ENVIRONMENTAL INVESTMENT

Philex, a socially and environmentally responsible Filipino company, commits to the continual improvement of its operation, also to minimize the adverse environmental impacts, to comply with relevant environmental legislations and to promote environmental awareness and commitment among its workers at all levels.

Even before the then President Marcos enacted the Anti-Pollution Law, the company started the construction of its first tailings pond in 1967. Two additional tailings dams were constructed subsequently as operation progressed. In addition to this, the company embarked on reforestation program even before the then First Lady Imelda Marcos embarked on her "Man and Biosphere Project".

Today, the company successfully reforested watershed, open, denuded and poorly stocked forestlands with an area of about 2000 hectares. More than 6 million seedlings of various species such as Benguet pine have been planted with a survival rate of 90%. Our present forest nursery has a capacity to produce 500,000 seedlings. The company has been recipient of various awards and citations on account of this reforestation program. The reforestation program creates employment opportunity to outlying residents since they are hired to undertake the seedling propagation, clearing and maintenance of the nursery and planted areas, fire breaks and fire protections and also during the planting season.

Other environmental management programs include:
a) Slope Stabilization and Erosion Control utilizing the benching, wattling and engineering methods
b) Water quality monitoring management at the Subsidence area. Regular monitoring of the effluent is conducted for various environmental

parameters. A Silt Pond was constructed to prevent siltation downstream and is constantly being maintained

c) Monitoring and Management of the three Impounding Systems to contain the mill tailings: From a daily tonnage of 25 thousand tons of ore milled, only about 200 dry metric tons of copper concentrate are produced and the rest forms the tailings. The company constructed three tailings pond, the first two ponds are already decommissioned; rehabilitation/ revegetation is progressive. Tailing Pond No. 3 is the active tailing impounding system. The company in partnership with Mines and Geosciences Bureau and Environmental Management Bureau through the Multi-Partite Monitoring Team (MMT) conducts regular audits to ensure the stability of the impounding systems. Regular monitoring of effluent is undertaken by the Mine Monitoring Team composed of the Local Government Units, the Indigenous Community representatives. Various sampling points were established in strategic areas in the operation to easily mitigate environmental aspects
d) Used oil and fuel management. The company established containment tanks in all industrial shops and used oil is collected at its sludge pond and sold to accredited buyers by DENR
e) Chemical and hazardous materials management is being undertaken at the Assay, Hospital and Industrial areas
f) Solid waste management. The company developed a portion of its Tailings Pond No. 2 as a Sanitary Landfill facility as permitted by the government.
g) Air quality and noise management in all areas of operation is also regularly monitored
h) Energy and Natural Resources Management is implemented in all aspect of the operations
i) Management of Subsidence Area: The Company undertakes backfilling operation activities on the surface above the active mining area in order to minimize subsidence and to ensure the safety of the underground workers.

Total environmental cost or total expenses for environmental management programs of Philex Mining Corporation in 2009 was PhP183.70 million, which is 5.8% of its Mining and Milling Cost. From 1967 to present, the company earmarked a total of PhP2.7 billion for its environmental expenses, representing 5.7% of its mining and milling cost. As per 1995 Mining Act, all mining companies are required to spend 3 to 5% of its mining and milling cost for environmental expenses.

HUMAN RESOURCE MANAGEMENT

Philex has a regular workforce of 2,131 and 480 under contractors. (As of January 2010) It has two (2) unions, the Philex Mining Supervisory Employees Union and the Philex Rank and File Employees Union – ALU-

TUCP for the rank-and-file employees, working hand-in-hand with Management for the continued improvement and sustainability of the Company.

The employees and their families enjoy the amenities of modern living within the mine site such as free housing, power and water services, free elementary education and a highly subsidized high school, free medical and dental care and services and recreational and sports facilities.

On Safety Performance, the company has tremendously improved on its safety performance for the last 20 years, from as high of 1,000 incidents a year in the mid-80's to an average of 30 incidents at present. This could be attributed to the mechanization of the operation and more importantly, due to the strict implementation of the Safety Rules and Regulations and Standard Operating Procedures, by adopting the International Safety Rating System.

SOCIAL INVESTMENT FOR THE HOST COMMUNITIES

Philex Mining Corporation has always been an active advocate of community development, recognizing that the operation is dependent on strong partnership with the community. Philex is committed to support and develop its host and neighboring communities under the Social Development and Management Program through the principle of partnership and people empowerment. It adopted the Participatory Approach engaging the communities to actively and meaningfully participate in community development as well as share in its resources, capabilities and responsibilities.

Philex Mining Corporation continues to be a strategic partner of its host communities towards their development thru its Social Development and Management Program (SDMP), which serves as a vehicle for the community to attain self-reliance and sustain their growth. The company has adopted the H.E.L.P. Program which stands for Health, Education, Livelihood and Public Infrastructure as its flagship program.

On health care, the company conducts an average of five medical and health missions, awareness seminars, herbal plant propagation and preparation, disaster preparedness, first aid training and sanitation program within its host and neighboring communities. Under its health care program, the company's Sto. Nino Hospital provided basic health services to an average of 6,500 patients a year from the communities free of charge.

Under the Education program, the company adopted several schools surrounding its operation, by improving the facilities as well as provided

essential equipment. The quality of educational programs for the dependents of employees as well as those from the host barangays remains of the highest standards. Primary education is free while secondary education is heavily subsidized. The Philex Mines Elementary School has an enrolment of 1,300 pupils with annual operating costs of 15 million pesos while Saint Louis High School-Philex has an enrollment of 1,000 students.
One of its flagship programs is the College and Secondary Education Scholarship, which provided opportunities to deserving and underprivileged students from the host to pursue their dreams. For School Year 2010-2011, the company supported 80 high school students and 46 college students in their education. The company also subsidized the education of about 280 elementary and high school students. The company participated in the Alternative Learning System of the Department of Education to enhance the reading and writing skills of OSYs/ illiterates and undergraduates and the first batch produced 31 learners who passed the national examination and were awarded their secondary education diploma. 18 out-of-school youth/residents availed of the Vocational Scholarship in partnership with Baguio School of Business and Technology College and the Philippine Institute of Mining and Quarrying.

On its Livelihood Program: The company supports the livelihood enhancement in its host communities. Initiatives which includes agro-forestry, honeybee keeping, mushroom production, livestock and aquaculture projects were introduced with the end result of providing the host and neighboring communities with self-sustaining activities. Alternative employment opportunities and training programs are regularly conducted to develop the entrepreneurial skills of the workers, their dependents and host communities.

To enhance employment skills, the company provided industrial skills and on-the job training on welding, auto-mechanic, heavy equipment operation and mechanic. Likewise, participation in the government programs such as Work Appreciation Program - a training program for new graduates, as well as the Special Education for Employment of Students (SPES) provides opportunities for students to earn for their education.

In support of the social service projects, the company implemented infrastructure projects such as farm to market road improvements, water/irrigation systems, constructed four hanging bridges, concreted pathways to facilitate delivery of services and products in the host and the neighboring communities of the mine site. Philex assisted in the reconstruction of Torre Elementary School, Camp 3 and Ligay Elementary School under the Third Elementary Education Program (TEEP) of the DECS, construction of Teachers quarter at Torre, Coop building at Multi-purpose building at Banget/Sal-angan, Ampucao Barangay hall and also in the construction of the Triumph of the Cross Catholic Chapel at Torre, Camp 3.

ECONOMIC BENEFITS

In 2008, the company paid the government a total of PhP334.6 million in direct and indirect taxes. Total payment up to the present amounted to more than PhP10 billion contributing to the coffers of the government for the development of the countryside.

The company paid the government a total of PhP1.29 Billion from 1991 to 2008 of taxes for mine products. From 1991 to 2002 wherein 40% went to the local government, 20% to the Province of Benguet, 45% to Municipalities of Itogon and Tuba and 35% to Barangay Ampucao and Camp 3.

Indirect impact of the presence of the mine is the emergence of micro-entrepreneurs, public markets and cooperatives, further contributing to the development of the area. In partnership with Philex Mining Corporation, the Philex Credit and Consumers Cooperative has become a hall of famers in the Cooperative Movement in the Philippines.

MINE TRANSITION PLANNING

As mandated under the New Mining Act of 1995, all mining companies are required to prepare for their Final Mine Rehabilitation and Decommissioning Plan. Philex Mining Corporation has also started preparing its closure plans. Base on its remaining mineable reserve of 69 million metric tons, the current declared life of the mine is eight years. The objective of Philex's Mine Transition Plan is to seek to minimize the dislocation caused by the termination of the operation as well as determine the best and most productive use of the land and facilities.

Last December 2009, the company launched its Community Business and Technology Center (CBTC), with the vision of making the Philex employees, their dependents and the host and neighboring communities be self-reliant and self governing. This is done by developing sustainable livelihood opportunities and matching it with business opportunities.

Four CBTCs were established, namely: The Meat Processing, Livestock Production, Aquaculture and Coffee CBTCs. These centers shall be avenues for building the skills of the employees, provision of access to market and capital and enhancement of management / entrepreneurial skills.

AWARDS AND CITATIONS

Various entities commended the Company for its efforts in the field of Safety, Environment and Community Development. The mine was conferred the "Safest Block Caving Operation award for the 17th consecutive year by the Philippine Mine Safety Environment Association (PMSEA). Awards and certificates of merits were also given by PMSA to individual mine employees of the company for their work and safety performances. It has continuously garnered the championship in the search for the Adopt-A-Mountain Adopt-A-Mining Forest Program of the Government. The company is also recognized by the Department of Labor and Employment as one of the Most Outstanding Firm with Family Welfare Program. The company has always been in the forefront during rescue and retrieval operations in the aftermath of calamities and emergencies around the country, thus earning a Presidential Award for Heroism and an Outstanding National Volunteerism Award.

In 2001, the company became the First Metal Mining Company in the Philippines with ISO 14001 Certification for its Environmental Management System, which is now on its 10th cycle.

CONCLUSION

Philex has come a long way – from its humble beginnings to a prime mover in responsible mining and the largest copper and gold producer in the country today. Philex will move on and will continue to carry on its role in responsible mining – building communities, creating job and opportunities, generating taxes and foreign currency through exports, making dreams and visions into reality.

With tons of copper, precious gold and treasured silver mined from the bowels of the earth, Philex becomes a nation builder. A prime example of what mining can do to generate wealth and to build up our country in an environmentally sustainable manner.

Truly Philex... is a Gift of God and a Work of Man.

BIOREMEDATION EFFORTS IN AN ABANDONED MINE AREA: THE MOGPOG, MARINDUQUE EXPERIENCE

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ABSTRACT

Various bioremediation strategies were carried out in an abandoned mine area in Mogpog, Marinduque. Since *Jatropha curcas* or physic nut (tubang-bakod Tag) is a plant that can tolerate a wide range of environment, its adaptability in the area was determined but in conjunction with various treatments such as application of lime and compost, and mycorrhizal inoculation. Compost incorporation improved biomass accumulation, giving heavier roots and stem than the untreated plants. Root, stem and leaf dry weights were heavier than in treatments with lime, or mycorrhiza alone. However, better growth performance was obtained under treatment combinations (e.g. compost and mycorrhiza, compost and lime). *Jatropha* seedlings planted under existing *Acacia auriculiformis* were generally taller and larger in diameter with a mean survival rates of 90-97%; while in an open site 80-93%. Biodiversification (i.e. planting with narra, banaba, anchoan and alibangbang, together with *Jatropha*), showed better performance of *Jatropha* in terms of height. Growth in terms of stem diameter had an opposite trend since shorter plants have apparently larger diameter. The results suggest that *Jatropha* grows faster where there is diversification, thus enhancing its growth in an abandoned mine area. Biodiversification effect on the rhizosphere bacteria appeared to vary with trees planted. Bacterial counts were higher where trees were diversified. Since seeds are processed for biodiesel, and the environmental concern that the heavy metals may lodge in the seeds, the translocation of heavy metals in *Jatropha* was also studied. The concentration of Zn was highest in the roots, Cu in the stems and Pb in the leaves in the control treatment. Applications of

compost and mycorrhiza greatly reduced the translocation of these heavy metals in the various organs. Analysis of the fruits and seeds revealed that heavy metals are nil or absent in these organs.

INTRODUCTION

First, I would like to acknowledge the members of this bioremediation effort: Dr Nelly S. Aggangan, Dr Nelson M. Pampolina, Prof. Arlene Llamado, Dr Jocelyn T, Zarate, Mayor Senen Livelo, Jr, and the head of our research team, Dr Asuncion K. Raymundo. As the saying goes, ***time leaves no one behind***...we all deteriorate thru time...and our environment is not spared. The over exploitation of our resources lead to the deterioration of our environment. This we can see in the patches of bare mountains where the forest has been felled, the overexploited mangroves resulting to denudation, etc. These destructions result in loss of biodiversity, climate change hazards such as flood, decrease of water storage, decline in food production, etc. **But time also heals**...For instance, the desert-like area somewhere in India has been transformed to an oasis in a span of less than two years. And as Klaus Becker said, "I saw all this green in what is otherwise a complete desert." They found that *Jatropha* cultivation can halt soil erosion, increase water storage in the soil and transform barren expanses into lush productive land.

In our project, we also tried *Jatropha curcas* because of the hype on this species as cheap source of biodiesel. It has also long been known to exhibit high resistance to aridity. In fact, it can even survive in deserts. But, can *Jatropha* be used as a phytoremediation species? Can *Jatropha* grow in an abandoned mine area considering that this is not just a simple case of being a marginalized land? Planting vegetables and other food crops in an abandoned mine area/ or converting it in an agricultural land is risky because of the danger of the heavy metals (HMs) entering the food chain. Planting non-food high value crops would be alright. So, planting biofuel crops like *Jatropha* would pose lesser risk. It is a "two-in-one" solution from environmental and economic points of view.

The research area where various bioremediation efforts were carried out is part of the 32 hectares of abandoned mine dump site Mogpog, Marinduque. It has a hilly topography, and at 60 m above sea level, it is almost plain. In addition, it is overlooking Mogpog Elementary and National Comprehensive High Schools and communities are present all around. Their location is put at risk because of the instability of the abandoned mine dumpsite. We thought that the area would be very ideal for our project because it has been abandoned for several years after extracting copper (Cu) ore,. Cu is one of the waste heavy metals present during the process of gold extraction from mining process. The environmental condition poses hazard to the community and all other living biota within the vicinity. Therefore, it is a priority site for rehabilitation to prevent leaching of heavy metals to the river system, agricultural areas, mangrove and marine ecosystems, not to mention the environmental and health risks posed in the communities around.

Although classified as an essential mineral element, copper could be very toxic in excess. Long-term exposure to copper can cause irritation of nose, mouth, and eyes, headaches, stomachaches, dizziness and diarrhea. Intentional intake may lead to liver and kidney damage, and worst, death. So, our research team tried to look into the adaptability/growth performance of *Jatropha curcas* in the abandoned mine area in conjunction with various bioremediation strategies, such as: (1) application of mycorrhiza and soil amendments like lime, and compost; (2) outplanting in open or under existing vegetation with or without mycorrhiza and soil amendments (3) biodiversification of *Jatropha* with fast growing reforestation species and its effect on the rhizosphere bacteria and concentration of heavy metals in soil; and (4) translocation of heavy metals in *Jatropha*. The latter study was an important component to determine whether the HMs are translocated to the fruits. If so, it would be an environmental concern since *Jatropha* seeds are processed for biodiesel. From among the treatments, we would also like to know whether the translocation of HMs could be contained to the lower region, particularly, the roots since the greatest risk of food chain contamination is in the shoot or leafy vegetables like lettuce or spinach. Another hazard is forage eaten by livestock.

FINDINGS

The soil in the abandoned mine area contained copper, lead, cadmium and zinc; but only Cu exceeded the maximum allowable limit. The amount of Cu in the soil was almost double that of the allowable limit of 36 mg/kg soil.

A. Effect of mycorrhiza and soil amendments

In this study, the treatments were lime, compost and mycorrhizal inoculation in the form of Mykovam and MineVam obtained from BIOTECH-UPLB. Outplanted *Jatropha* seedlings with no compost and lime exhibited the poorest growth. Tallest and biggest diameter were observed in seedlings treated with Mykovam or MineVam plus compost and lime. Mycorrhiza plus lime and compost gave the highest leaf, stem and root dry weights.

B. Growth response of *Jatropha* outplanted in open or under existing vegetation

Soil analysis in open area was slightly acidic and poorer in organic matter (O.M.) content as compared with the soil with existing vegetation. However, the amount of P and K were almost the same. Seedlings planted in areas with existing auri, talahib, silver fern, datiles and anabiong showed 90-97% seedling survival when planted under *Acacia auriculiformis*, while 80-93% survived under open site condition.

C. Biodiversification of Jatropha with fast growing reforestation species and its effect on the rhizosphere bacteria

In this study, *Jatropha* seedlings were interplanted with some indigenous forest tree seedlings such as narra, anchoan, banaba, alibangbang and their combinations. Soil samples around the rhizosphere were analyzed and examined for bacterial population. Our results showed that the population of heavy metal- resistant bacteria varied in each block or stand. Soil from pure *Jatropha* block gave the lowest number of heavy metal -resistant bacteria while soil from the stand where *Jatropha* was outplanted with narra and anchoan had the highest heavy metal-resistant bacteria. Higher counts of bacteria, however, were observed under more types of trees planted with *Jatropha.* Total heterotrophic bacterial counts from the rhizosphere tended to increase with plant diversification. The importance of microbial diversity in soil habitats is critical to the maintenance of soil health and quality. The increased microbial populations with plant diversification, as observed in our study, could pave the way to a faster improvement and rehabilitation of heavy metal contaminated soils.

D. Translocation of heavy metals in *Jatropha curcas*

Elements can be classified based on their mobility: mobile, intermediate and immobile. Cadmium, for example, is classified as a mobile element, while lead is immobile; and Cu and Zn exhibit intermediate mobility. Under certain circumstances, the intermediate elements are mobile. Our results showed that without mycorrhizal treatments, Cu tend to accumulate in the stem; Zn in the roots; and Pb in the leaves. However, with mycorrhizal treatments, high concentration of Cu, Zn and Pb were obtained in the roots. This indicates that the translocation of these HMs to the upper portion of *Jatropha* seedlings was regulated by mycorrhizal treatments. Several studies have reported that mycorrhizal infection generally enhances metal uptake to the roots of some plants but not to the shoots which means that HMs are retained in mycorrhizal root systems. On the other hand, cadmium (Cd) uptake was nil to zero because the concentration of this HM in the soil was already below the detectable limits.

The amount of HMs in the fruits was also below the detectable limits indicating that the HMs were not and/or minimally translocated to the fruits.

CONCLUSIONS

Our findings showed that *Jatropha* can be grown in an abandoned mine area provided that soil amendments are applied. Compost alone can enhance the growth of *Jatropha*. Although mycorrhizal application can enhance the growth of *Jatropha*, its growth could be better improved if combined with compost. The best growth of *Jatropha*, therefore, was observed when all treatments were combined (i.e. lime + compost+ mycorrhiza). Total heterotrophic bacterial counts from the rhizosphere tend to increase with plant diversification. Mycorrhizal treatment increased the root/shoot barrier of *Jatropha* for HMs and, thus, may play a role in regulating the translocation of HMs like Cu, Pb and Zn, as well as enhancing the heavy metal resistance of the plants.

ACKNOWLEDGEMENT

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APPLICATION OF BIOREMEDIATION IN THE CLEAN-UP OF THE MARILAO-MEYCAUAYAN-OBANDO RIVER SYSTEM IN THE PROVINCE OF BULACAN

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ABSTRACT

The Marilao-Meycauayan-Obando (MMO) River System in the province of Bulacan is the focus of the clean-up project of the stakeholder group organized by the Blacksmith Institute. The river system is considered to be a "hot spot" of water quality. The water from the river system feeds into thousands of hectares of active fishponds and finally drains into the Manila Bay. The objectives of the paper are to present 1) the process of initial assessment conducted by Blacksmith Institute and subsequent findings on the water quality of the MMO River System, 2) the strategy jumpstarted for the river clean-up, and 3) the opportunities for bioremediation within the clean-up framework.

The water quality exceeds environmental standards, posing health risks primarily from consumption of aquatic life forms containing heavy metals. Sources of pollution are the gold refining industry, tanneries, lead recycling, open dumpsites, and legacy sites. The problem is estimated to have started more than half a century ago when environmental laws were not as stringent compared to the present. Both formal and informal sectors are engaged in industrial activities and do not have waste treatment facilities where untreated industrial effluent are generally dumped into the water bodies of the MMO River System.
The river clean-up strategy focused on a holistic approach starting with the organization of a stakeholder group which was part of the development of a river management strategy that involved environmental assessment and monitoring, identification of sources of pollution, controlling pollution at source, clean-up of contaminated sites, enforcement mechanism, research

and development, and Information Education Communication. The stakeholder group eventually formally spun-off into a Water Quality Management Area supervised by a Board in accordance with RA 9275 otherwise known as the Clean Water Act. Remediation options ranged from use of microorganisms, chemicals and physical approaches. Large scale polluted sites and industrial activities dominated by the informal sector indicated that bioremediation is a promising cost-effective solution.

INTRODUCTION

The Marilao-Meycauayan-Obando (MMO) River system (MMORS) in the province of Bulacan is the focus of the clean-up project of the stakeholder group organized by the Blacksmith Institute. The river system is considered to be a "hot spot" of water quality. The water from the river system feeds into thousands of hectares of active fishponds and finally drains into the Manila Bay. The objectives of the paper are to present 1) the process of initial assessment conducted by Blacksmith Institute and subsequent findings on the water quality of the MMO River System, 2) the strategy jumpstarted for the river clean-up, and 3) the opportunities for bioremediation within the clean-up framework.

In 2007, MMO River System was considered as one of the most polluted places in the Philippines by the Blacksmith Institute for a number of reasons. The MMO river system water quality is said to have exceeded environmental standards in some parts, posing health risks primarily from consumption of aquatic life forms containing heavy metals. Ground water in some areas are found to be contaminated with chromium and arsenic. The main sources of pollution in the river system are the gold refining industry, tanneries, lead recycling facilities, industrial and manufacturing facilities, open dumpsites, and legacy sites along the river system. Smelting and gold refining, which are components in jewelry-making, entail the use of a large amounts of acids, specifically nitric acid. Tanning uses chromium, a heavy metal, in the process and the effluent is mostly directly discharged into the river system. Furthermore, leachates also find their way into the river system through a number of unmanaged open dumpsites found along the riverbanks. In the same region, agricultural (like poultry and swine) farms, fisheries, wet markets, slaughter houses, and residential areas can be found. Their effluents can also end up into the river system (Figure 1).Furthermore, nine regulated heavy metals, such as arsenic, cadmium, copper, lead, mercury, manganese, nickel, and zinc, were also detected within the area. These heavy metals are found within the confines of the water quality management area.

Figure 1. Mapping of various agricultural, textile and manufacturing industries found within the water quality management area along the MMO river system.

It seemed to be very unusual to have all these sources of pollution in just one geographical location. Geographically, the northeastern part of the MMO River System is the Sierra Madre mountain ranges and in the southwest is Manila Bay. Whenever it rains in the Sierra Madre catchment area, the water drains through a number of tributaries including the MMO river system and exits to Manila Bay carrying with it the pollutants. Surrounding the MMORS are the municipalities of Sta. Maria, Marilao, Meycauayan, Obando, Valenzuela, San Juan del Monte, Caloocan, and Quezon Ciy (Figure 2).

Figure 2. Municipalities surrounding and along the water quality management areas of the MMO river system.

The pollution problem in the MMO is believed to have started more than half a century ago when environmental laws were not as stringent compared to the present and where most of the associated industries causing the problem have been in the area for a long time. Both formal and informal sectors are engaged in industrial activities and do not have waste treatment facilities where untreated industrial effluent is generally dumped into the water bodies of the MMO river system.

MMO RIVER SYSTEM CLEAN-UP STRATEGIES

Approach 1: Stakeholder group formation

The process of MMORS clean-up was formally started in 2003. The river clean-up strategy focused on a holistic approach starting with the organization of a stakeholder group (Figure 4) which was part of the development of a river management strategy that involved environmental assessment and monitoring, identification of sources of pollution, controlling pollution at source, clean-up of contaminated sites, enforcement mechanism, research and development, Information Education Communication, and organizational development. The stakeholder group eventually formally spun-off into a Water Quality Management Area (WQMA) supervised by a Board in accordance with RA 9275 otherwise known as the Clean Water Act (in 2008).

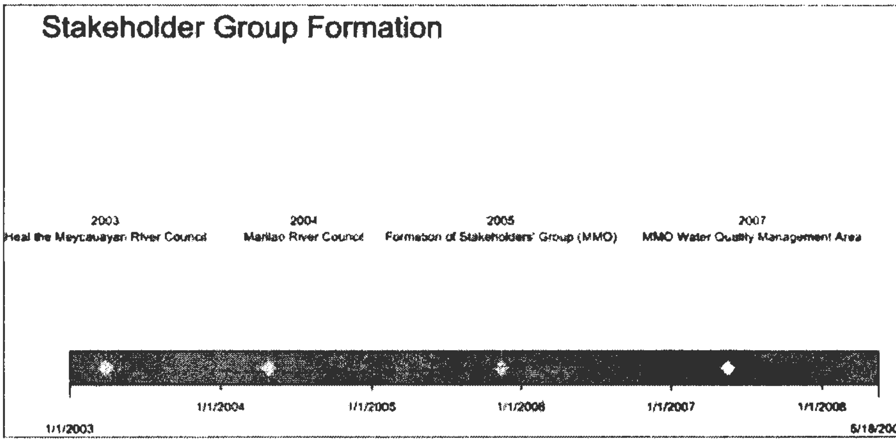

Figure 3. Steps involved in stakeholder group formation for the management of MMO river system.

Approach 2: Conduct of baseline studies

To help identify the best options on how to approach the MMORS pollution problem, the following research activities were undertaken:

- River quality monitoring – Wet and Dry Season (Prof. M.D.Mendoza)
- Mass balance of the tannery and gold smelting operations in Meycauayan, Bulacan (Project Leader (PL): Dr. C Alfafara)
- Mapping of extent of heavy metal pollution in public places in Meycauayan and Marilao, Bulacan (PL Dr. LC Trinidad)
- Knowledge, attitude and perceptions of community members on heavy metal pollution (PL Prof. MET Mendoza)
- Occupational health study of workers in gold smelting and tannery industries (PL Dr. VP Migo)
- Heavy metal bio-accumulation in most commonly cultured fishes in the MMORS (PL: Dir. MD Mendoza and Dr. G. Cruz)
- Health risk and health assessment studies (PL: Dr. L Panganiban)
- Fish consumption studies (PL: Prof. MET Mendoza)

Instead of allocating more funds to do regular environmental assessment work involving some more than 30 sampling sites (Figure 4), it was decided to allocate more resources to do action researches after baselines have been established. The abovementioned studies were undertaken to help formulate sound strategies and management decisions as well as initiate remediation measures in the MMO area. The details of the respective studies are not presented in this paper but the respective project leaders can be contacted for further information and discussion.

Figure 4. Monitoring points along the MMO river system.

Approach 3: Pilot-testing of cost-effective technologies for SMEs

The MMO–WQMA is faced with the challenge of dealing with the industrial informal sector that comprises most of the operators which are point sources of pollution. Dealing with the informal sector poses huge challenges considering that they are not formally recognized or registered. But in terms of contribution to the problem, they account a lot and merely clamping on them is not an effective approach as demonstrated in several cases where they would simply transfer to other areas within the WQMA. The action-research projects being undertaken primarily target the informal sector considering that they comprise the magnitude of the point sources of pollution.

In partnership with the Department of Science and Technology (DOST), the Blacksmith Institute was able to develop and install a pilot wet and dry scrubber in two gold smelting workshops. Precious metals refining and jewelry making produces air, water, and sediment pollutants, hence the need to address all the pollutants. The scrubber is designed to capture the particulate matter, especially the heavy metals, and also the highly acidic emissions in the refining process. Inside the scrubber is caustic soda to neutralize the acids. Charcoal is used instead of activated carbon, which is more expensive to trap the particulates.

For the household solid wastes, some 10 portable biogas digesters developed by the DOST was installed in a number of households and also another one in a backyard piggery to test for the digesters feasibility and effectiveness. The biogas digester is able to produce at least 50% of the household fuel needs in cooking their food.

A cost-effective solution in recovering silver has been developed as well by using an electrolysis set-up. This technology is said to be able to recover about 99.9% of silver used in the process. Previously, copper rods or bars were used as electrodes to sequester silver. However, copper can also be released in the wastewater as an indirect pollutant. This probably could explain why there was an increased amounts of copper in the river water. The mentioned solution includes the selection of appropriate electrodes to recover silver, thereby getting rid of the use of copper bars and rods. The electrolysis set-up is promising because of its effectiveness and low investment.

Approach 4: Capacity building and mobilization of industry to control pollution at source

The stakeholder groups previously formed were actively participated in training courses, seminars and workshops. Consultation meetings and technology transfer seminars with gold smelting workshop owners and jewelry associations were done and are still continuing, as well as capacity building and mobilization.

Approach 5: IEC campaigns

A number of information and education materials were developed to disseminate mature research technologies and also to create awareness of the problem and corresponding solutions. Among the target audiences were community leaders, industry owners and workers, health workers, teachers, and staff of local government units.

Approach 6: Leveraging resources and building partnerships

The Blacksmith Institute is able to leverage some of its resources and access fundings, here and abroad. The local government units and the national government are also now putting in counter part resources to fund pollution control and remediation efforts. Discussions are also being held with the the Asian Development Bank (ADB) and the World Bank thru the DENR for possible inclusion of the MMO in their priority programs.

Among the project partners and funders include the Blacksmith Institute, the Department of Environment and Natural Resources, the Provincial Government of Bulacan, LGU Marilao, Meycauayan and Obando, University of the Philippines Los Baños, Asian Development Bank, The Coca-Cola Foundation, Green Cross Switzerland, and the DOST.

OPPORTUNITIES FOR BIOREMEDIATION

The problems presented above are being approached from several directions and in various methods. The approaches depend on the scale and the urgency. Remediation options ranged from use of microorganisms, chemicals and physical approaches to address heavy metals and organic pollutants. Some contaminated public places are being remediated through stabilization method, whereby use of naturally-occurring or indigenous materials and minerals are being done. Local and imported zeolites are being tested for their efficacy in stabilizing contaminated set-ups using the toxicity characteristic leaching procedure (TCLP). Stabilization methods can be done in two ways: 1) on-site stabilization,or 2) removal of contaminated substrates from the site and treated on a separate facility.

POSSIBLE APPLICATION OF BIOREMEDIATION

- River Remediation
    - phytoremediation for heavy metals
    - use of microbes for BOD reduction aided by oxygen-releasing compounds (ORC) which is very promising
- Treatment of contaminated soil in public places (i.e. treatment on site with earthworms and phytoremediation);
- Treatment of tannery wastewater for BOD reduction using sewage treatment plants and aided by ORC; chromium precipitation using naturally occurring flocculants (mineral or plant-based);
- Treatment of wastewater of gold smelting workshops (i.e. copper recovery by biogenic hydrogen sulfide), and;
- Treatment/rapid decomposition of solid wastes through microbial action

PROPOSED MMO RIVER MANAGEMENT PLAN

Phase I – Controlling Pollution at Source
- Identification of all possible sources of pollution
- Organizing of industries by Sector
- Controlling pollution at source by Industry
- Regulatory measures and strict enforcement of environmental laws
- Joint Monitoring of the Industries by Government, LGUs, NGOs Industries

Phase 2 – Remediation and long-term river management strategy
- Dredging of highly contaminated sites
- Construction of landfill for low-level heavy metal wastes
- Construction of centralized wastewater treatment facility
- River cleanup and remediation
- Zoning/relocation of industries in appropriate areas
- Riverbank stabilization
- Municipal solid waste management

Support Programs
- Environmental Assessment/Monitoring
- Capacity Building of the WQMB
- Occupational and Community Health Surveillance Program
- Information, Education, Communication to Raise Awareness

ECOTECHNOLOGY FOR RESTORATION
OF POLLUTED RIVERS AND LAKES

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ABSTRACT

Inland freshwater bodies being used as water source are under severe stress due to modern urbanization and industrialization in their catchments all over the world. The fouling of water bodies to present eutrophication levels accelerated in nineteenth century due to industrialization and subsequent population growth. In a period of about two decades, the situation is worsened, though there were no significant changes in microclimatic factors. But there were huge changes in consumption of water resources for drinking and industrial purpose in the urbanized areas which led to more production of wastewaters. Conventional mechanistic approaches of wastewater treatment needed uninterrupted electricity supply for their desired performances which has become a prohibitive factor in using them for waste management. Secondly, they have not proved efficient against the non-point sources of pollution. That's why; there is a need of an alternative approach which can be less energy intensive and simpler as far as routine operations are concerned. Application of ecotechnology emphasizing on zero use of electricity is found to be suitable for increasing the biodiversity while converting waste into resources. Global warming and climate change are the new threats of this millennium. Waste management without man-made inputs and energy would be useful in abating the impact of waste degradation on climate change. Hence, in the regional environmental and resources planning with waste management, ecosystem approach may yield ecological harmony among the urban systems and water bodies. Ecological designs will help in mitigating the negative impacts of development to ensure Urban System with Ecological Security (USES). In this paper, ecotechnological options for restoring the quality of polluted rivers and lakes have been discussed in detail for its role in reviving the self-purification capacity of the water body and revitalizing their endemic biodiversity. Udaipur, India's case study of ecological restoration was also discussed in this paper.

Key words: urban pollution, lakes and rivers, ecotechnology, restoration, self-purification

INTRODUCTION

Urban pollution is a common problem all over the world. Various kinds of pollutants are unscrupulously released into the environment which includes SO_2, NO_x, CO_2, hydrocarbons from vehicles, organics and nutrients like nitrates, phosphates from the sewage, highly toxic metals, organics from industries, etc. The list is very long. But the efforts to curb ever spreading pollution including legal, technical, technological, individual are sporadic at local, regional or national levels. Many examples of severe river and lake pollution can be cited in developed and developing countries[1,2]. The well known examples in India are of Yamuna and Ganga rivers. These rivers are highly polluted by the disposal of millions of litres of sewage, industrial wastewaters and thousand tons of garbage and solid waste. According to one estimate, 18 rivers of India are highly polluted and need immediate action to control the pollution and further damage[3]. Even in Pune, the rivers Mutha, Mula and Pawna can be considered dead rivers which receive wastes from industries and societies[4]. The lakes of Hyderabad have received plenty of pollution[5].

The impacts of pollution, on natural resources like rivers, lakes, groundwater, aquatic biota, forests, animals, birds and human being also are very perilous and economically disastrous as in the case of Marilao and Mecauyan River System[6,7]. Resources utilization and waste generation increased multifold in last few centuries after the industrial revolution creating enormous stress on freshwater bodies which are sources of drinking water for the cities, towns and irrigation water for agriculture to ensure food security[8,9]. Eutrophication of rivers and lakes is cause of concern for most of the provincial and national governments. Now, the deteriorated quality of water in rivers and lakes is compelling the world leaders to take up the mission of treating the discharges from the urbanized sprawls. Contaminated water bodies undergo anaerobic degradation releasing green house gases contributing to global warming[10,11,12].

AEROBIC AND ANAEROBIC TECHNOLOGIES FOR WASTEWATER TREATMENT

Conventional technologies inclusive of mechanistic systems for degradation of pollutants aerobically or anaerobically are normally employed to treat the pollution from point sources. They are not that much effective against non-point sources of pollution. It has been estimated that Pune city will need about 3000 MW electricity to run its sewage treatment plants based on conventional energy intensive technologies[13]. In other words, to generate that much electricity daily 3000 tons of carbon dioxide will be released into the environment. This CO_2 emission factor is based on the data generated by the Department of Energy of USA in association with the Environment Protection Agency[14].

Conventional biological treatment of wastewater is heterotrophic biodegradation of pollutants e.g. activated sludge, trickling filter and anaerobic digester etc. It is observed that under favourable conditions, heterotrophs grow and multiply rapidly. They are coalesced in the aggregates which are removed by simple gravity precipitation. In the aerobic systems, organic matter is partly assimilated in the biomass (secondary sludge) and partly converted into carbon dioxide and water. These systems require electricity to run the mechanistic systems to maintain the bacterial cells and pollutants in contact. Sometimes, chemical inputs are required as pretreatment to attain the desired quality of wastewater to be processed by heterotrophic system. Therefore, the conventional systems become more energy intensive, chemical intensive and costly to be maintained by skilled personnel only.

LIVING SYSTEMS IN THE TREATMENT OF POLLUTION

It's a two-prong action – detritus-feeding organisms consume the pollutants (because its nutrient for them) and wastes (mineralized products) generated from them are useful for green plants and secondly, the green plants absorb carbon dioxide from the atmosphere. Thus, the pollutants get transferred to natural cycles i. e. biogeochemical cycles of carbon and other elements. Carbon gets stored in vegetation and subsequently in the soil. Plants store carbon in the forms of live biomass. Once they die, the biomass becomes a part of the food chain again and eventually enters the soil as soil carbon. This is a natural process which doesn't need electricity at all. Hence, the ecotechnologies – using ecological engineering principles to treat pollution – have immaculate advantage on energy intensive technologies[15]. The role of vegetation in carbon deposition is the suitable option which offers the potential in human systems to function as a carbon sink.

The Kyoto Protocol to the UN Framework Convention on Climate Change has provided a vehicle for considering the effects of carbon sinks and sources. Vegetation is considered as important carbon sink. Biomethanation, cogeneration and afforestation for the control of pollution are well sought activities to control climate change.

Use of vegetation for pollution control will give an added advantage to comply with the Kyoto Protocol and to gain the carbon credits. SERI's ecotechnological products such as Soil Scape Filtration, Green Bridge, Green Lake, Hydrasch Succession Pond, Green Channel[16] etc. give such advantage at negligible consumption of electricity over the conventional mechanistic systems.

Ecotechnology is an applied knowledge and skill that searches for accomplishing human needs with minimal ecological disruption, by binding and subtly maneuvering natural forces to leverage their beneficial effects. It is the 'ecology of techniques' and the 'techniques of ecology,' requiring a substantial understanding of the structures and processes of ecosystems and societies.

All sustainable engineering that can reduce damage to ecosystems, adopt ecology as a fundamental basis, and ensure an orientation of precaution in the implementation of the conservation of biodiversity and sustainable development may be considered as forms of ecotechnology[17].

APPLICATION OF ECOTECHNOLOGICAL SOLUTIONS FOR POINT AND NON-POINT SOURCES OF POLLUTION

Applications of ecological engineering principles, chemical and microbiological reactions, interactions of multi-cellular organisms and succession of biological communities are very useful to consume organic and inorganic pollutants from the wastewaters and bioconvert, render them into non-toxic form, finally transferring the elements in the ecological cycles[18]. These eco-transformations, eco-conversions and degradation or bio-utilization of pollutants - nutrients are the part of ecological cycles - biogeochemical cycles. Various technologies like Green Bridge, Green Lake Eco-Systems, Green channel, BIOX (Biological Oxygenation) and Stream Eco-Systems have been developed in last two decades to address the pollution from point and non-point sources.

Table 1. Ecotechnologies for pollution control

Source of Pollution	Applicable Technology	Prerequisites
Point – residential, commercial, hospital and industrial	Soil Scape Filter, Hydrasch Succession Pond, Green Channel	Area 1 sq. m/1000 lit. Area 3 sq. m/1000 lit. Area 1 sq. m/1000 lit. Wastewater pH 6 – 9
Non – point – sources polluting rivers, streams and lakes	Green Bridge, Green Lake, With LOTS, BIOX, BEST etc.	Stream course and its flood plain and shoreline area, no encroachment

Soil Scape Filter

It is the simulation of natural filtration process of water through the good vegetated soils and fragmented rock materials below which purified water percolates down in the form of groundwater. Soil Scape filter contains layers of bio-active (i.e. biologically activated) soil - ECOFERT – a mixture of heterogeneous microbes having ability to degrade the pollutants. The process harnesses ecological principles of interactions and interrelationships of living systems with their environment and eco-transformations of substrates into assimilable - absorbable form by treating, transforming and detoxifying the pollutants using solar energy.

Figure 1. Treatment of industrial wastewater using soil scape filter

Figure 2. Treatment of residential school wastewater using soil scape filter

It has been experienced in a school in Baroda, India that 50 cubic meter (cu m)/day sewage without segregation of solids is being treated using Soil Scape filtration with use of 8 units electricity, since there is no gravity benefit. So, only pumping is needed. The treated BOD is less than 16 mg /L since from the last 4 years after the plant became operational. By conventional method, it would have required at least 50 units of electricity every day with some additional cost for consumables and chemicals.

In one food processing unit about 50 km from Pune, India, 30 cu m industrial wastewater having COD of more than 1000 mg/L and BOD of more than 440 mg/L is being treated from last the 4 years with consistent outlet COD and BOD less than 70 mg/L and 32 mg/L respectively complied with local pollution regulatory norms such as 250 mg/L for COD and 100 mg/L for BOD. They have found it very cost effective as electrical consumption is reduced to zero for waste management.

The coloured effluents from the textile units are also treated using Soil Scape filtration system. The colour reduction in two stage filtration system is consistently more than 90%. These plants are successfully running in Baroda and Jaipur, India from the last 5 years. The precursors of dyes and pigments are also treated considerably - up to 95% COD reduction – the biological system found to be adapted to such difficult pollutants.

Hydrasch Succession Pond

It applies ecological successions of aquatic plants – such as floating, submersed or rooting species - depending on characteristics of incoming effluents. Various green plants are successfully employed to treat organic and inorganic pollution using phytofiltration and phytoremediation processes. It is open water system, confined by rooting plants, surface covered by floating plants with various trophic levels flourishing depending on the limiting factor of incoming nutrients.

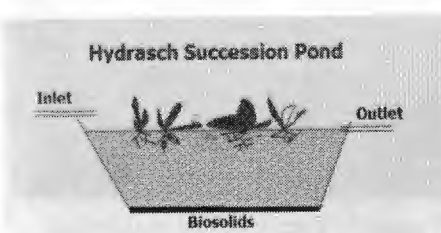

Figure 3. Schematic diagram of Ecological system – Hydrasch Succession Pond

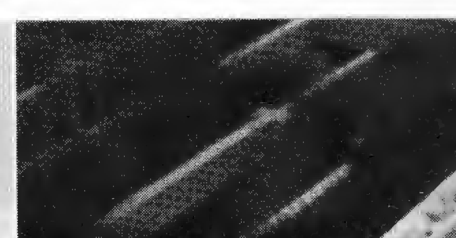

Figure 4. Installation of Hydrasch Succession Pond to absorb heavy metals from electroplating wastewater

This was proved to be very effective for the treatment of metallic wastewater from electroplating industry with domestic wastewaters. This mixed wastewater contained organic pollutants with heavy metals like hexavalent chromium, nickel and copper etc. The natural phenomenon of adsorption of positively charged metals on negatively charged organic matter was one of the key processes in this treatment system. The metal reduction is noted up to 99% in the system.

Stream Ecosystem

It uses natural slopes of polluted drains, beds, banks of streams or pond to augment the aerobic activity in water by creating turbulence and providing shallow depths to allow sunlight to penetrate the water column. This is a simulation of stream flow in the wilderness. It facilitates the free flow of water splashing due to stones and cascades. It is observed in stream - tributary treatment project in Pune installed in 2004 that the dissolved oxygen in the water increases multifold – in some already installed systems. This increase is up to 90 – 120 times (i. e. from 0.1 to 8 – 12 ppm)[19].

Natural streams, rivers and lakes have their own in - built purification system, the winds, natural slopes, stones, sand, biological growth and complex food web help in the purification process. The basis of food web is nothing but utilization of one's waste by another as its food. Nature has her own living machinery of detritivorous microbes and other living species to consume wastes. These principles have been harnessed in the Stream Eco-System Technology.

Figure 5. Photograph of a stream – tributary having flow 22 MLD mixed with domestic and automobile service stations

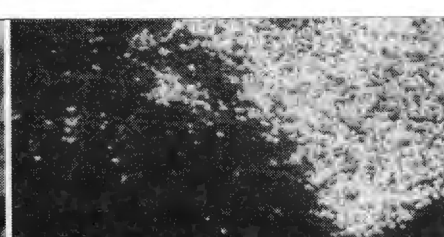

Figure 6. Floating species increase dissolved oxygen in water

Phytofiltration, BIOX Process and LOTS

Biological Oxygenation (BIOX) and Lentic Oxygenation Treatment Systems (LOTS) involve the use of plant fibres, roots to remove suspended solids from wastewater effectively in a well-designed tank. In these techniques normally, the floating plants and natural gradients are used to facilitate the increment of oxygen in the water.

Biological oxygenation process is defined as the transfer and dissolution of oxygen with the help of certain green plants and algae. It has been observed that in the unpolluted mountain streams, the oxygen content in the water rises up to 19 ppm.

Green Bridge Technology

The Green Bridge ecotechnology applies filtration power of biologically originated cellulosic/fibrous material in combination with sand and gravels and root systems of green plants.

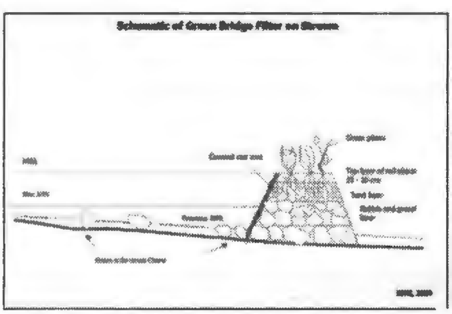

Figure 7. Schematic diagram of Horizontal filtration – Green Bridge

Figure 8. Installation of Green Bridges on a stream – tributary having flow 70 MLD

It's an innovative approach to minimize the cost of pollution treatment when the cellulosic/fibrous materials like coconut coir or dried water hyacinth or aquatic grasses are compacted and woven to form a bridge/porous wall like structure strengthened by stones and sand. All the floatable and suspended solids are trapped in this biological bridge and the turbidity of flowing water is reduced substantially. The green plants growing there help in absorption of soluble substances including heavy metals.

First of such innovative systems was developed in the College of Military Engineering (CME), Pune in 2003. The system was installed on highly polluted industrial and domestic wastewater having flow more than 70 MLD. It was joint efforts of SERI with CME, Clean River Committee and Cummins Foundation. Then two more such projects were developed on another highly polluted stream - tributary in Pune. The advantage of this technology is that it takes 1/5 time that of conventional systems to install and commission. It does not require any additional land or electricity or cement. It is developed with locally available material only. Even after 4 years of installation, the parameters of treated water found to less than that of receiving river Mula of Pune.

Green Lake Technologies

It can be integrated with Green Bridges. Green Lake system uses floating, submerged or emergent aquatic plant species. These can be termed as macrophyte ponds also. Macrophytes are capable of absorbing large amounts of inorganic nutrients such as N and P, and heavy metals such as Cd, Cu, Hg and Zn, etc., and to engineer the growth of microbes to facilitate the degradation of organic matter and toxicants.

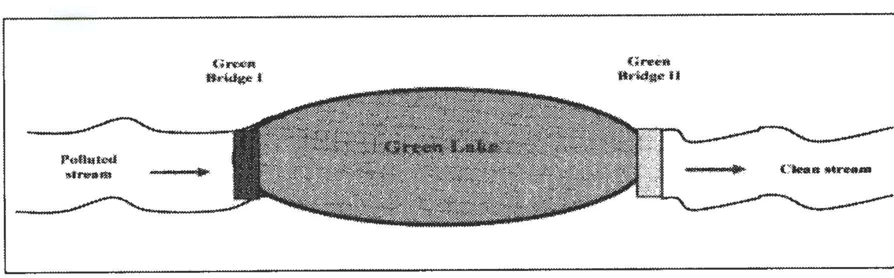

Figure 9. Schematic Diagram of Ecological system-Hydrasch Sucession Pond

Ecological Restoration of Ahar River, Udaipur, India 2010

Studies of Lake Ecosystem processes indicated the deteriorating status of Udaisagar and Ahar River. Dissolved Oxygen (DO), an important limnological parameter, were found to be zero in most of the samples tested. Fishes especially and other aquatic life was affected severely due to pollution in Udaisagar Lake having an area of about 1000 ha depending on the suitable concentration of dissolved oxygen in water[20].

Ahar River of Udaipur collects the domestic and industrial wastewaters from its urbanized (about 0.5 million population) and industrialized areas (mine smelters, textile, chemical, etc.). Total flow of the river is estimated to be 150 MLD as dry weather flow. In the monsoon, it is observed that the floodwater flow increased to a maximum of 3000 MLD sometimes. The robust system was expected to be designed to withstand such high and flash floods. Considering the hydraulic and pollution loading the grafting of Green Bridge was planned with stimulation to augmentation of local biota and self-purification capacity of the river. The green bridge system installed to revive Ahar River is shown in the following figure.

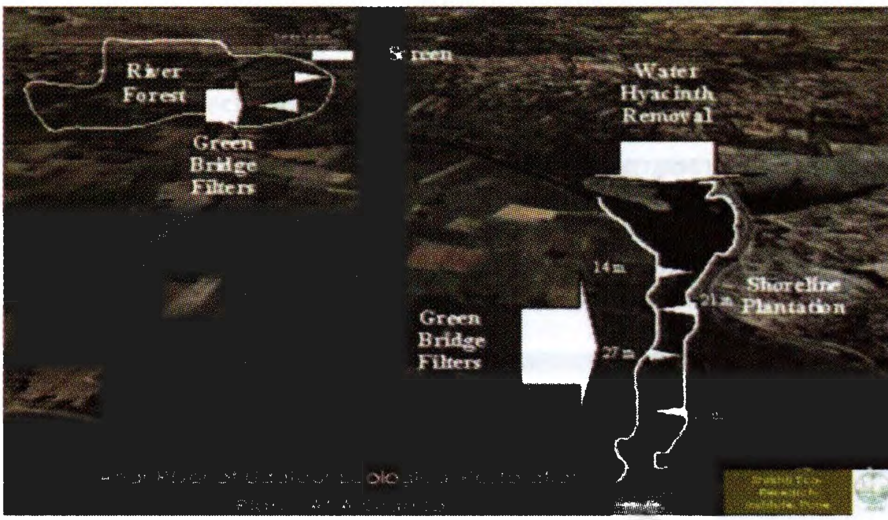

Figure 10. Conceptual plan of ecological restoration of Ahar River, Udaipur, India

The first noticeable effect of the attempts of reviving self-purification capacity of the Ahar River was the increased level of dissolved oxygen in the river which was confirmed by a number of laboratory analyses and field observations. Moina species was found to be plentifully growing. It consumed planktonic materials as the ecotoxicity was reduced due to Green Bridges and mixed bacterial cultures. The result was encouraging as dissolved oxygen content of the water improved to 7 - 8 mg/L during day time from absolute nil in the untreated stretch of the Ahar River.

Local villagers spotted turtles and snakes in the river again within 7 days after the complete installation of green bridges. Bird-watchers observed increased number of bird species in and around the river. People also noticed the absence of any stench in the ambient air, improvement in well-water quality and substantial reduction in foam in the river.

The major observations are highlighted as:

1. BOD and COD reduction due to Green Bridges was found to be in the range of 50 – 78%.
2. There are pertinent observations by local villagers and farmers of about complete elimination of odour problem and more than 90% reduction in foam in the river.

APPLICATION OF ECOTECHNOLOGY FOR ECOLOGICAL RESTORATION OF RIVERS AND LAKES

While working on ecosystem approach for the restoration of rivers or lakes, now it has become essential to consider their catchments[21,22] for effective implementation. Various activities[23] for restoration programmes of water bodies are identified as :

A. Restructuring of City Plans incorporating concepts of "Protected Green River Zones" and "Waste Management" considering environmental pollution impacts of development on stream, river or lake in every sector like rural, urban, industrial, agricultural, etc. Scope of river catchment area development, policy and planning must include: river culture, river science, river engineering, and river technology.
B. Evolution of administrative and techno-professional institutional mechanism to control and treat discharges from the industrial, agriculture and urban areas to achieve zero pollution discharge target using decentralized, community driven, water & wastewater technologies and strengthening of auditing system in water use & wastewater treatment sectors with societal wisdom and people's participation. Appropriate budget must be allocated for water and wastewater management to achieve zero pollution discharge into streams, rivers and lakes

C. Integrated water resources conservation and management for achieving the water balance by implementing afforestation, rainwater harvesting, water recharge, and pollution treatment to avoid inter basin transfers and linking of rivers. In the wake of limited success of conventional technologies and chemical intervention in maintaining the river clean for sustainable development, the natural eco-remediation potential in the river catchment area must be harnessed and optimized.

For example, Marilao and Meycauayan (MMO) River System in the Philippines has urban population interspersed with industrial clusters and solid waste disposal facilities. The catchment is shown in the following figures –

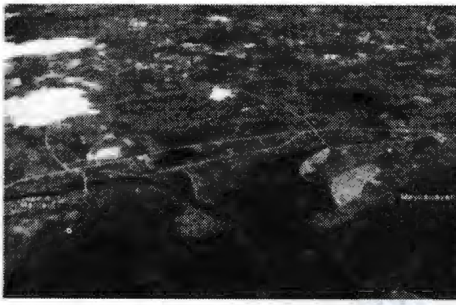

Figure 11. Google image of MMO River System

Figure 12. The Ecological system – Hydrasch Succession Pond

As per the studies and reports of Blacksmith Institute referred earlier, the MMO river system is highly polluted due to untreated discharges from industries especially tanneries, sewage from the settlements and leachates from the solid waste sites. The river water is severely polluted and emits foul odours. For the restoration of such polluted rivers, Ecosystem Approach and ecotechnological systems considering geo-climatic conditions, pollution load, sources, and ingress points can be adopted with judicious selection of technologies which do not require electricity and which are self-sustaining with minimal maintenance and monitoring.

This will involve six pillars- model of Integrated Lentic and Lotic Basin Management (IL^2BM). These pillars are namely policy (involving national, provincial and local governments), information and knowledge (studies of research institutes), institutions (government agencies and research), participation (involvement of local citizens), technology (suitably applicable and affordable) and finance (sustainable support from funding agencies). The collective efforts based on these principles will lead to effective management of water resources.

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BIOREMEDIATION OF MARINE OIL SPILLS: GENERAL GUIDELINES AND THE CASE OF SOLAR 1 OIL SPILL

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ABSTRACT

Marine oil spills cause extensive damage to important ecological and fisheries resources in marine coastlines on both long and short term periods. Clean up strategies include mechanical removal of oiled sand layer, skimming of oiled waters, sediment relocation, and *in situ* burning, application of dispersants, emulsifiers, solidifiers; and bioremediation. Bioremediation involves either *in situ* biostimulation through the addition of nutrients to enhance natural biodegradation processes of indigenous oil-degrading microorganisms or *ex situ* techniques where contaminated materials are transported to another location for treatment. However, because of the complexity of bioremediation, its effects are often controversial. Furthermore, field tests of bioremediation have been limited in the subarctic and temperate zones in most cases, and few trials have been done in the subtropical and tropical zone. On August 11, 2006, the country experienced the worst oil spill to date from the Sinking of M/T Solar 1 off the coast of southern Guimaras. It affected many marine organisms including coastal communities. This presentation will present some guidelines on bioremediation technologies for a marine environment; results of the 28-day monitoring study on simulated biostimulation in oil-contaminated shoreline areas using sand collected from the experimental fields mixed with crude oil (weathered Bunker C) in the ratio of 0.02 g of crude oil to 1 g of sand supplemented with fertilizer (Osmocote-14-14-14) exposed at beach and mangrove areas; and updates on the status of oil spill impacts within Taklong Island National Marine Reserve, Nueva Valencia, Guimaras.

INTRODUCTION

Various types of organic pollutants contaminate the marine environment (Head and Swannell, 1999). Among these pollutants, hydrocarbon contamination resulting from oil spills poses the greatest risk. Most oil spills are accidents involving tankers, oil rigs, storage tanks, pipelines, barges and other vessels (IPIECA, 1995). Every spill is different. The differences stem from the amount and type of oil, initial physical and chemical characteristics of oil, prevailing climatic and sea conditions, and whether the oil remains at sea or is washed ashore (ITOPF, 2010). Since 1974, the International Tanker Owners Pollution Federation Ltd. has recorded nearly 10,000 incidents involving accidental spillages from tankers, combined carriers and barges except those resulting from acts of war (ITOPF, 2010). Among these are – the sinking of the *Atlantic Empress* off Tobago, West Indies in 1979 releasing 287,000 tons of oil and; the sinking of *Prestige* off the coast of Spain in November 2002 that resulted in the release of 63,000 tons heavy fuel oil (HFO) contaminating over more than 2,000 kilometers and the most publicized grounding of T/V *Exxon Valdez* on Bligh Reef in Prince William Sound, Alaska, USA Alaska that released 37,000 tonnes of oil (ITOPF, 2010). Details of other oil spills statistics are available at http://www.itopf.com/information-services/data-and-statistics/statistics/index.html. From this database, approximately 5.71 million tones of oil were spilled involving tanker accidents from 1970 to 2010.

In the Philippines, on December 18, 2005, more than 364,120 liters of Bunker C spilled from a ruptured Napocor Power barge No. 106 off Caybelo Cove, Semirara Island, Antique, into mangroves, seagrass beds, tidal flats and coral reefs around and within the cove. The Semirara oil spill was considered the first largest incident recorded in Philippine waters. Among the seriously damaged habitat was the 23.5 ha mature natural mangrove stand (Sadaba et al., 2006 unpubl.). However, on August 11, 2006, the Philippines experienced the largest spill to date when the oil tanker M/T Solar 1, carrying more than two million liters of bunker fuel, sank off the coast of southern Guimaras affecting also parts of Iloilo and Negros Occidental (Yenden, 2008). In Guimaras, over 200 kilometers of coastline have been affected including the 1,100 ha Taklong and Tandog Island National Marine Reserve (TINMR) in Brgys. Lapaz and San Roque, Nueva Valencia. The marine reserve has 26 species of mangroves distributed in 37.51 ha mangrove area (Sadaba et al., 2009a) (Figure 1).

Figure 1. Oiled mangroves within Taklong island National Marine Reserve, Nueva Valencia, Guimaras during the Solar 1 Oil spill on August 11, 2006

These events led to the increased awareness of the public, thanks to the widespread media coverage, on the risks involved in the transport of oil and oil products. In 2007, the Philippine Coast Guard organized The National Stakeholders Consultative Meeting for the Revision of the National Oil Spill Contingency Plan (NOSCP) that led to its promulgation in 2008. The NOSCP will serve as the guide for better response for the containment and recovery of oil such that negative impacts on the marine environment will be avoided or minimized because the occurrence of oil spills will most likely continue to happen in the country (Phil Coast Guard- NOSCP, 2008).

OIL CHARACTERISTICS AND IMPACTS

The impacts of marine oil spills is dependent on a number of factors that include the type of oil; oil loading (the thickness of deposits on the shore); geographical factors; climate, weather and season, biological and physical characteristics of the area; relative sensitivities of different species and biological communities; and clean up and rehabilitation efforts (IPIECA, 2008; Dicks, 1999). Among these factors, oil type seemingly has the most influence. The American Petroleum Institute (1999) defined oil "as complex mixture of thousands of different compounds, composed primarily of carbon, hydrogen, sulfur, nitrogen and oxygen. Hydrocarbons (composed solely from carbon and hydrogen atoms) are the most abundant compounds found in crude oils." It also classified oil as either non-persistent oils and persistent oils. Non-persistent oils consist of light refined products that are highly volatile and of low viscosity. As such, they do not normally persist on the sea surface for longer periods since their volatile components rapidly evaporate, are easily dispersed and dissipated. However, they pose a significant fire hazard and explosion, and are a source of public health concern if they occur close to centers of population. High concentration of toxic components can cause significant environmental impact but the effects will be highly localized. Examples of non-persistent oils include Light diesel, Naphtha, Marine gas oil, Marine diesel fuel (API, 1999; Swedish Coast Guard, 2002; White, 2005; National Research Council, 2003). Persistent oils include heavy crudes and heavy fuel oils; the latter are oils which form a stable water-in-oil emulsion ("chocolate mousse"). Such oils are highly persistent since they contain a greater proportion of non-volatile components, and are characterized by high viscosity. Persistent oils can travel further away from the original spill site and may contaminate fragile coastal habitats resulting in significant economic and environmental losses. Examples of persistent oils include Fuel Oil No. 3-6, Bunker C; Bunker fuel, Marine fuel oil, Intermediate bunker fuel (API, 1999; Swedish Coast Guard, 2002; White, 2005; National Research Council, 2003). The choice of the best response to an oil spill can, therefore, be made when there is information on the type of oil spilled and its characteristic for prediction of its probable fate and effects under prevailing environmental conditions (ITOPF, 2002; White, 2005).

Marine oil spills cause extensive damage to important ecological and fisheries resources in marine coastlines in both the short and long terms (Dicks, 1999; O'Sullivan and Jacques, 2001). In Guimaras, results of the three months post-spill assessment showed mortality of mangrove trees, saplings, and wildings that accounted to 0.932 ha of the entire areas affected in Guimaras (Sadaba et al., 2009a). Among the 29 species affected in the island-province, only five showed mortality: *Avicennia marina* (0.03%), *Rhizophora apiculata* (0.16%), *R. mucronata* (0.26%), *R. stylosa* (0.46%), and *Sonneratia alba* (0.04%) (Sadaba et al., 2009b). The results of the three month assessment captured only the acute effects (i.e., tree, sapling, and wilding mortality). However, the observed acute damage may be insignificant when compared to the longer-term chronic stress induced in mangroves by the stranded and residual oil. Economic losses cover toxicity, tainting and damage to property such as nets, pumpboats and other fishing gears (IPIECA, 2008). In southern Guimaras, the incident has done great harm to the livelihood of fishermen, some of whom have found employment as cleaners of the oil spill.

RESPONSE OPTIONS

Response options to the impact of the oil spill would be dependent on several factors. It would be determined by the amount of oil involved, the type of oil, the conditions prevailing in the area, when the incident happened, and where. Based on guide book titled "Characteristics of Response Strategies: A Guide for Spill Response Planning in Marine Environments" published by American Petroleum Institute, National Oceanic and Atmospheric Administration, the US Coast Guard, and the U.S. Environmental Protection Agency in 2001, the following are three windows of opportunity in the period following a marine oil spill:

a) *very early period* - oil is fresh and concentrated near the discharge source; open for one to two days; responders focus on source control, containment near the source, and removal. This is the best opportunity to reduce adverse environmental impacts.

b) *early period* - the oil has spread and no longer concentrated; the oil is already in a position to threaten sensitive resources and habitats; window may be open for several days to weeks.

c) *later period* - the oil has stranded; opportunity to respond may be open for days to months, or longer; responders select the habitat-appropriate shoreline cleanup options to minimize further damage to the environment.

During the Semirara oil spill, shoreline clean-up techniques included manual removal of oil, the use of rice straws as absorbents (Figure 2) as well as the use of commercially available adsorbent pads. The cleanup of the shorelines in Guimaras also employed similar techniques but local clean up workers included the use of improvised oil spill boom made of bamboo wrapped by rice straws to contain the oil prior to removal (Figure 3). The clean up at sea done by the Philippine Coast Guard focused on the application of chemical dispersants (ITOPF, 2010).

Figure 2. Rice straws as absorbent materials used at Semirara Oil Spill, Antique.

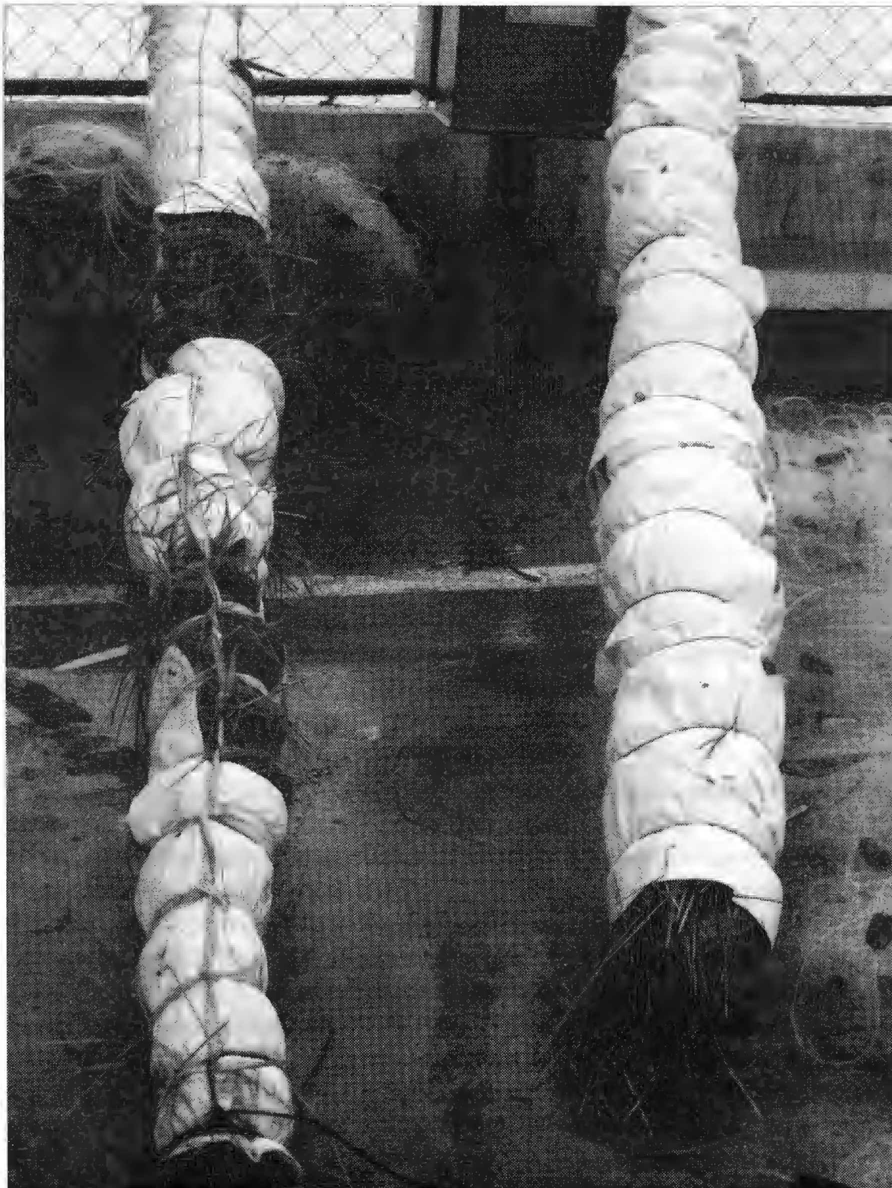

Figure 3. An example of an improvised spill boom made of rice straws wrapped with commercial adsorbent pads used during the Solar 1 Oil spill at Brgy. La Paz, Nueva Valencia, Guimaras

Numerous strategies have developed for the oil spill response including booming, skimming, barriers/berms, physical herding, manual oil removal/cleaning, mechanical oil removal, sorbents, vacuum, debris removal, sediment reworking/tilling (IPIECA, 2000; API, 2001). Details of the aforementioned strategies and others are found on Characteristics of Response Strategies: A Guide for Spill Response Planning in Marine Environments jointly published by API, NOAA, US Coast Guard, and EPA.

BIOREMEDIATION OF MARINE OIL SPILLS

In the system of responses to an oil spill, bioremediation is classified under "Other countermeasures" and "Waste management" (Walker et al., 1993). Bioremediation is defined as "the act of adding materials to contaminated environments to cause acceleration of the natural biodegradation processes" (OTA, 1991). According to Atlas and Cerniglia (1995), *bioremediation aims to accelerate the natural attenuation process through which microorganisms assimilate organic molecules to cell biomass and produce by-products such carbon dioxide, water and heat.*

An important factor affecting bioremediation is the condition of microorganisms. The microorganisms must be active and healthy and must be able to enzymatically attack the pollutants and convert them to harmless products (Vidali, 2001; Leahy and Colwell, 1990). In order to facilitate bioremediation, it is advisable to assist the microorganisms' growth and increase microbial populations by creating optimum environmental conditions to detoxify the maximum amount of contaminants at maximum rates (Atlas and Bartha, 1981; Atlas, 1988; Atlas and Cerniglia, 1995).

The factors used to determine the specific bioremediation technology include the type of microorganisms present, the site conditions (i.e., temperature, waves energy, etc.), and the concentration and toxicity of contaminant chemicals (Head and Swannell, 1999; Lee et al., 1995). Numerous species of microorganisms are known to degrade petroleum components such as the bacterial genera of *Achromobacter*, *Acinobactor*, *Alcaligenes*, *Arthrobacter*, *Bacillus,Brevibacterium*, *Cornybacterium*, *Flavobacterium*, *Nocardia*, *Pseudomonas*, *Vibrio* (Floodgate, 1984; Atlas and Cerniglia, 1995), *Alcanivorax* and *Cycloclasticus* (Harayama et al, 2004); *Ochrobactrum* (Sivaraman et al., 2011). *Alcanivorax* is responsible for alkane biodegradation, whereas *Cycloclasticus* degrades various aromatic hydrocarbons (Harayama et al., 2004). Various genera of fungi have also been isolated as oil-degraders such as *Penicillium*, *Aspergillus*, *Rhizopus* (Mancera-Lopez et al., 2007), *Candida* and *Rhodotorula* (Miranda et al., 2007), *Articluosporium* and Zoopage (Onifade and Abubakar, 2007), *Aureobasidium*, *Sporobolomyces*, *Trichoderma*, *Mortierella*, *Corollospora*, *Dendryphiella*, *Lulworthia*, *Varicosporina* (Leahly and Colwell, 1990). Identification of key organisms that play a role in degradation of pollutants is important for the development of bioremediation strategies (Cohen, 2002).

In the marine environment, biodegradation of oil is affected by a number of factors such as oxygen, nutrients and temperature. Nutrients such as nitrogen, phosphorus and iron are usually low and may result in slow rate of biodegradation (Lee and Levy, 1989; Bragg et al., 1994; Atlas, 1995). Oxygen is also an important requirement for hydrocarbon degraders and is not a factor limiting the rate of biodegradation on or near the sea surface or just below the surface of beaches where aeration is provided by wave and tide action (OTA, 1991). However, it becomes a problem in areas with fine sediments or in low-energy beaches. Biodegradation of oil has been observed on a wide range of seawater temperature (Floodgate, 1984). At low temperatures, the rate of hydrocarbon degradation decreases (Floodgate, 1984).

Bioremediation strategies involved either a) bioaugmentation involving the addition of oil-dgrading microorganisms; and 2) biostimulation involving the addition of nutrients or growth-enhancing substances for stimulation of indigenous oil degraders (Lee, 2000). Studies have shown that bioaugmentation was not an effective strategy based on field studies (Lee et al., 1997; Venosa et al., 1991, Swanell et al., 1996) while biostimulation through fertilization with phosphorus and nitrogen was found to be effective for marine oil spills (Atlas and Bartha, 1973, 1992; Prince, 1993; Swannell and Head, 1994).

Bioremediation has both its advantages and disadvantages. Its advantages include the minimal physical disruption of a site while other clean -up options involving physical and chemical procedures may cause additional damage to the biota; the overall cost is much lesser compared to the other options requiring more labor and equipment (Atlas, 1995).
The main disadvantage for bioremediation is that significant short term results are not readily observable (Swannell et al., 1996). It is probably not appropriate as an initial defensive measure when high amounts of oil are present and its application might also be site-specific as conditions are highly variable.

BIOREMEDIATION STUDIES RELATED TO SOLAR 1 OIL SPILL

1. Biodegradation of Heavy C Oil by *Alcanivorax* sp. A1 Strain Isolated from Recovered Bunker Oil Spilt in the 'Solar1' Accident

This study was conducted by Takeshi Yoshikawa, Kei Murata, Seiichi Uno, Jiro Koyama, Hiroto Maeda, Masazumi Hayashi, and Resurreccion B. Sadaba published in Memoirs of the Faculty of Fisheries Kagoshima Univ., Special Issue, pp. 67-73, 2010. It has as its main objective the determination of the oil degradation capability of the isolate for potential application in ex-situ bioremediation.

In this study, biodegradation of n-alkanes as well as PAHs and alkylated PAHs by *Alcanivorax* sp. a1 was speculated. This is important from the bioremediation points of view, since *Alcanivorax* spp. is known to play a major role in the restoration of oil-polluted marine environments by assimilating petroleum-derived alkanes exclusively, but few reports have been made at PAH and alkylated PAH biodegradation by this genus so far.

Microbial degradation of alkylated PAHs, one of the major constituents of crude oil and tend to remain in oil-polluted environments for a long time, has not yet been well understood. In order to obtain direct evidences, more detailed investigation including enzymatic activities and genetics involved in non-substituted and methyl-substituted PAHs would be necessary.

2. Isolation and Screening of Bioremediating Fungi

Sheen-screen method as described by Brown and Braddock (1990) was modified and employed to test the degradation potential of fungal isolates. A 1 x 106 spore suspension was prepared using 1.5% NaCl solution in distilled water. 100 uL of spore suspension was inoculated in 1.8 mL of Bushnell-Hass Broth supplemented with 2% NaCl in each of the 24 wells. Three wells were inoculated with each isolate and a drop of fresh Bunker oil was overlaid on each well. The wells were incubated at 25 ± 2°C and observed for 3 weeks. Disruption of the oil signified positive results for Bunker oil degradation potential. Growth of fungal mycelia and sporulation were also noted. A total of 390 isolates were selected for purification, storage and screening for crude oil degradation potential. Thirty-five (35) different isolates were initially screened for its potential to degrade bunker oil (Fig.4). Wells were observed for 2-3 weeks. On the first week, no disruptions of oil or growth of fungi was observed. By the third week, twenty-two (63%) of the isolates screened were positive for crude oil degradation. Disruption of oil is in the form of aggregation of oil components, disruption at the edges or margins, and disruption or clearing of the overlaid oil. Growth of fungi was also observed on the overlaid oil in some of the wells. Growth is in the form of mycelial formation or sporulation.

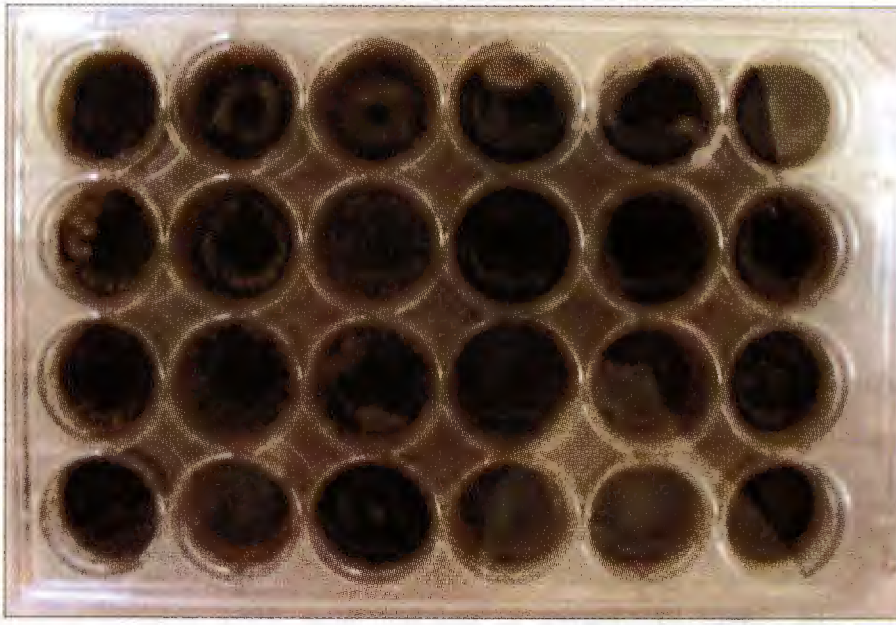

Figure 4. Fungal isolates growing on Bushnell-Haas medium overlaid with bunker oil demonstrating hydrocarbon-degrading potential.

The findings in the study indicate that the application of bioremediation of marine oil spills is a promising technology, although more field and laboratory studies are needed. The indication is that there is a need to include bioremediation protocols and guidelines in the National Oil Spill Contingency Plan.

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PHILIPPINE SEAWEEDS AS BIOREMEDIATION AGENTS

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ABSTRACT

Philippine seaweeds, particularly carrageenophytes and alginophytes, have been observed to adsorb heavy metal ions in solution. This property is mainly due to the anionic polysaccharides present in their cell walls. Carrageenans found in red seaweeds have ester sulfates while alginates found in brown seaweeds have uronic acids that serve as the main sites of heavy metal binding, together with other minor anionic sites. Brown seaweeds under the genus *Sargassum*, which is found ubiquitously in the intertidal areas of the country, is also being considered in removing phthalates that have leached out from plastic materials through biosorption. Seaweeds are also utilized as biofilters to clean effluents from fish ponds and to remove excess nitrogen from the water before being released to the sea. This is important in the practice of integrated multi-trophic aquaculture and in marine environmental biotechnology applications.

INTRODUCTION

Eutrophication as well as heavy metals and plastic pollutions pose major environmental threats primarily in the marine ecosystem. Eutrophication occurs when nutrient enrichment commonly and persistently exceeds that of the normal level (Carpenter, 2005) and this phenomenon is observed in many coastal areas worldwide. This is largely due to anthropogenic sources such as agricultural, industrial and domestic activities (Karydis, 2005).

The hazards of eutrophication to the marine environment include the induction of harmful algal blooms and the sudden decrease of dissolved oxygen levels in the water leading to anoxic conditions. In the study of Azanza et al. (2005), fish kills on the mariculture area in Bolinao, Pangasinan was known to be caused by the bacterial degradation of the collapsed *Prorocentrum minimum* bloom, resulting in the fatal reduction of dissolved oxygen levels (hypoxia). The *P. minimum* bloom was suggested to be caused by ammonia, nitrite, nitrate and phosphate enrichment in the area where high mariculture activities have been observed (San Diego-McGlone et al., 2008). A study conducted in Manila Bay showed that it exhibited high phosphate level in the sediment (David et al., 2008), which complemented periodic *Pyrodinium bahamense* var. *compressum* bloom (red tide) that could cause paralytic shellfish poisoning (Azanza, 1997). Moreover, levels of heavy metals such as lead (Pb), cadmium (Cd), and mercury (Hg) among others, have been observed to increase significantly in various marine environments, which can be attributed to combustion of fossil fuels, mineral ore minings, hydrometallurgical processes, and other anthropogenic activities (Duruibe et al., 2007). Accumulation of these heavy metals in water columns coincide with heavy metal accumulation in the tissues of some edible marine mollusks (Lacastesantos-Fernandez, 2004) and echinoderms (Soualili et al., 2008). Different tissues of fishes were also found to accumulate heavy metals (Ashraf, 2005; Kalay et al., 1999). The consumption of marine organisms that bioconcentrate heavy metals could cause chronic or acute biotoxicity to humans (Duruibe et al., 2007). Moreover, phthalates that can easily leach from plastics have been associated with reproductive and developmental biotoxicity in humans (Bucher, 2008), though these compounds were not observed to bioaccumulate in marine organisms (Mackintosh et al., 2004).

There are some 820 seaweed species in the Philippines, of which 350 species have economical usage. In spite of the diverse seaweed species, only about 18 species are economically important (Trono, 1999). Though most of the commercially important seaweeds are used as raw material for phycocolloids extraction, other applications for the otherwise non-economically viable seaweed species are now emerging, including their utility in bioremediation. Hence, in this study, the utilization of seaweeds as bioremediation agents was explored.

Seaweeds as Bioabsorber of Heavy Metals and Phthalates

Philippine seaweeds such as carrageenophytes and alginophytes have been observed to adsorb heavy metal ions in solution. *Eucheuma striatum* which produces κ-carrageenan, and *Eucheuma spinosum* which produces ɩ-carrageenan were reported to be effective in heavy metal binding. Their ability to bind metal ions have been attributed to the anionic polysaccharides present in the cell walls of these seaweed species. Carrageenans found in red seaweeds have ester sulfates while alginates found in brown seaweeds have uronic acids which can both sequester heavy metals through cationic interaction (Veroy et al., 1980). In the study of Wahbeh (1985), though green and brown seaweeds could also absorb heavy metals, red seaweeds could concentrate them the most. Moreover, different species of Sargassum were tested for their adsorption performance. *Sargassum filipendula* showed 0.66 mmol/g Cd adsorption at pH 4.5 while *S. fluitans*, *S. vulgare* and *S. filipendula* showed Cu adsorption of 0.80, 0.93 and 0.89 mmol/g, respectively (Davis et al., 2000). Additionally, alginophytes were used to remove heavy metals in waste water treatment. The suggested particle size of seaweed was 350 to 600 um and 40 minutes contact time for efficient adsorption. The optimum dosage application of seaweed for effective removal of iron and manganese was 500 mg/L, which gave the removal efficiency of 38.90% and 52.90%, respectively (Ishak and Hamzah, 2010). On the other hand, Gezgin et al. (2001) found several species of red and brown algae containing o-phthalates which was believed to be derived from their environment. Furthermore, it was found that *Sargassum siliquastrum* could be used to bioabsorb di-(2-ethylhexyl)-phthalate with the removal capacity of 6.54 mg/g (Chan et al., 2004).

Seaweeds as Nutrient Biofilters

Seaweeds could also be utilized in bioremediation of eutrophic environment through nutrient absorption. In the study of Rodrigueza and Montaño (2007), three species of *Kappaphycus* substantially reduced the ammonium content of a fish mariculture farm effluent. The seaweeds attained maximum growth rates while their carrageenan content was improved, although no significant effect on its quality was observed. Moreover, seaweed farms, particularly of the agar-producing *Gracilaria* species, can be established on water channels that serve as buffer of water levels for fish and prawn ponds during high and low tides to absorb nutrients produced by fish feeds and fish manure.

The co-culture of *Gracilaria lemaneiformis* and *Sebastodes fuscescens* has estimated mean nitrogen and phosphorus uptake rate of 10.64 and 0.38 umol/g dry weight, respectively. It was also observed that *G. caudata* grown in a shrimp farm wastewater showed removal of NH_4-N at around 59.5%, NO_3-N 49.6% and PO_4-P 1.3% (Zhou et al., 2006). *G. verrucosa* was also observed to uptake NH_4-N, NO_3-N, NO_2-N and PO_4-P. There was a decrease of 54.12% NH_4-N, 75.54% NO_3-N, 49.81% NO_2-N and 49.00% PO_4-P in cultures with *G. verrucosa* (Soriano et al., 2009). *G. birdiae* also showed the ability to decrease PO_4 concentration by 93.5%, 34% of NH_4 and 100% of NO_3 after a 4-week experimental period (Huo, 2010).

Green seaweeds such as *Ulva* spp. could be utilized in recirculating water systems of aquarium such as in Ocean Adventure, Manila Ocean Park and as the final algal scrub to remove dissolved nitrogen. In the integrated multi-trophic aquaculture (IMTA), seaweeds are being used as part of the multi-species farming to absorb dissolved inorganic nutrients. The IMTA ventures into farming several marine organisms from diverse trophic levels in one time. IMTA creates a balanced system essentially following what has already been taking place in the ocean (Cullis-Suzuki, 2009). In the IMTA, fed species such as finfish and inorganic extractive species such as seaweeds and organic extractive species such as deposit-feeders are grown in one culture (Troell et al., 2009). IMTA systems are intended to mitigate the environmental problems caused by various types of fed aquaculture. *Graciliaria chilensis* is commercially cultivated and experimental studies proposed that it is an efficient biofilter in IMTA systems. Integrating *G. chilensis* aquaculture with salmon farms improves the productivity and physiological performance of *G. chilensis*. The biofiltration efficacy of *G. chilensis* was also confirmed through this experimental set-up (Abreu et al., 2009).

CONCLUSION

Aside from serving as sources of food, fertilizers, personal care products, nutriceuticals and medicines, seaweeds can also be a tool to help clean the environment. Seaweeds could be an effective bioindicator of marine pollution monitoring. Due to its efficiency in accumulating heavy metals and sequestration of excess nutrients for its growth utilization, seaweeds can also be an agent for bioremediation – either through direct application or through incorporation as part of IMTA.

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ADVERSE EFFECTS OF POLLUTANTS ON HEALTH

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ABSTRACT

"The degradation of the environment has become a major global problem, outstripping its local public health dimensions and becoming a serious threat, perhaps even to human survival in the long run." Human exposure to pollutants occurs through several routes such as inhalation, ingestion and skin contact. Such exposure leads to development of adverse health effects. The lecture will discuss the following: environmental impact sequence, the factors that increase the risk of adverse health effects to environmental pollutants (chemical and physical characteristics of agents, exposure situations and individual factors), health effects of pollutants (acute and chronic), major toxicologic concerns in addressing environmental risks (multiple exposures, chemical interactions, individual susceptibility, etc.) and strategies in addressing toxicologic concerns (regulatory safeguards, risk-reduction interventions, health surveillance, monitoring and treatment protocols, education and advocacies).

The following lecture focuses on a review of what is the environmental impact sequence; what are the factors that increase the risk of adverse health effects to environmental pollutants with a review of some of the studies that have been done locally with regard to health effects of pollutants; identifying the major toxicologic concerns in addressing environmental risks; and an outline of strategies in addressing toxicologic concerns.

It is necessary to consider the entire sequence of events from the pollutant source to its final health effects. The environmental health impact sequence starts with identifying and describing the sources of pollutants, their fate in the environment, and how these are transported. These pollutants will eventually become available for exposure in any member of the ecosystem. It is important also to consider the dose or dosage of these pollutants that get into the body and the health effects associated with such exposure.

FACTORS THAT INCREASE THE RISK TO ADVERSE HEALTH EFFECTS

There are three factors that increase the risk of adverse health effects that need to be considered: these are (1) the chemical and physical properties of the substance (or the agent), (2) the exposure situation, and (3) the individual factors and practices.

When talking about a particular agent or substance, one needs to describe its chemical and physical properties. It is important to take note of its physical state, solubility, reactivity, vapor pressure, and its ability to be transformed into other harmful forms.

The exposure situation describes four parameters, namely, (1) the duration of exposure--how long one is exposed to a certain agent or substance (whether immediate or long-term exposure), (2) the frequency of exposure (or how often one is exposed), (3) the dosage, and (4) the route by which an individual is exposed to the agent such as dermal route (or through the skin) or the most common and said to be the easiest route which is by inhalation. One can simply avoid exposure to certain substances by refraining from eating particular food, or by drinking purified water, but one cannot simply stop breathing to avoid exposure to atmospheric contaminants.

The third factor may increase the risk of adverse health effects is the individual. A number of people would ask why some people get sick while others do not,even though they live in the same environment. This is where the individual factor comes in. The individual factor takes into account the age, the gender, individual nutritional status, a host of genetic factors, and of course, the general health status. Equally important also is the individual practices--how one handles certain chemical substances and what is an individual doing with these.

ACUTE AND CHRONIC HEALTH EFFECTS

Two types of health effects are given: one would be the immediate (or acute) health effects and the delayed toxicity or the chronic effects. Acute health effects occur or develop rapidly after a single administration of a substance or exposure to it. For example, if a noxious gas is discharged in a room, it is a single exposure and signs and symptoms can develop immediately, or the signs and symptoms can manifest within 14 days from the time of exposure. For some substances it can be repeated exposures within 13 hours of the day, or if inhalational, within 4 hours of the day.

Other examples are the exposure to organophosphates which are commonly found in pesticides, heavy metals such as lead and mercury, and cyanide. Organophosphates act on an enzyme system that breaks down the neurotransmitter acetylcholine. Acetylcholine is responsible for the parasympathetic effects, which is also called as cholinergic effects. When the organophosphates inhibit the enzyme so that there will be no enzyme that breaks down acetylcholine, it results to an individual with very pronounced cholinergic effects which are manifested as sweating, diarrhea, salivation, dilatation of pupils, slowing of the heart rate, to mention a few.

In the case of mercury, when it gets spilled in the environment, it vaporizes easily. When the mercury fumes are inhaled this can lead to what is known as metal fume fever which mimics flu-like symptoms.

Cyanide is a very hazardous chemical which can be found in a number of jewelry cleaning agents. However, despite its toxicity, this substance is said to be very much available in the country. Exposure to this substance can cause coma, acidosis, and seizures.

ACUTE EFFECTS OF BUNKER OIL SPILL IN GUIMARAS, 2006

The oil spill in Guimaras in 2006 is said to have affected 4,000 households within the area as estimated by the provincial government. Initial examinations of the affected households within 100 meters from the shoreline presented acute effects of bunker oil which primarily was respiratory in nature due to the presence of various hydrocarbons in the spilled bunker oil. Other effects included dizziness, dermatitis. The complaints of stomach aches might be due to consumption of contaminated fish. During that time, there was an increased incidence of hospitalization, based on the report of the provincial health office, because of respiratory illnesses. Furthermore, much of the population examined were the people who worked in the oil spill clean-up. They were found to be ill-protected and wore no protection from toxic compounds present in the spilled bunker oil.

Because these workers were not appropriately attended to, the Department of Health had to intervene and provided these clean-up workers the complete health evaluation and the personal protective equipment.

ACUTE CLINICAL MANIFESTATIONS AMONG 208 FARMERS EXPOSED TO PESTICIDES IN BENGUET (2003)

The farmers were noted to complain of nervous system effects such as dizziness and headaches; eye pain, eye itchiness and redness, blurring of vision; weakness, skin itchiness, and confusion after being exposed to pesticides due to widespread spraying in their respective area. These farmers belonged to the cut-flower industry which, during that time, was not yet organized with regard to what types and amount of pesticides are only needed to avoid the use of harmful mixtures of pesticides. Besides, these farmers were not well-protected from exposure to these mixtures of pesticides.

DELAYED TOXICITY (CHRONIC HEALTH EFFECTS)

Delayed toxicity, also known as long-term effects, occurs after a lapse of some time (usually months or years). The difficulty in detecting these long-term effects is that they can mimic the usual illnesses that may develop by a person in his or her lifetime. It is important to look into long-term effects of harmful and toxic compounds. These can be manifested as neuropathies, reproductive effects (including sterility, spontaneous abortion, difficulty in pregnancy, hereditary defects, etc.), developmental effects, cancer, respiratory problems and hematologic illnesses.

MERCURY AS A HEALTH HAZARD DUE TO GOLD MINING AND MINERAL PROCESSING ACTIVITIES IN MINDANAO, PHILIPPINES, 2000 (Bose-O'Reilly *et al.*)

About 323 miners (ball-millers and amalgam smelters) from Diwalwal, local families from Monkayo and a control population (in Davao) were examined by Bose-O'Reilly et al. (2000). The examiners found that those who were engaged in mining activities (the ball-millers and amalgam smelters) and were exposed to mercury used in gold extraction had respectively 55% and 61% mercury levels above toxicological threshold limits (blood mercury >15 µg/L; urine mercury>25 µg/L). High percentage of population in Mt. Diwata area (ball-mill workers: 65%, amalgam smelters: 85%), 33% in non-occupationally exposed population in Mt. Diwata and downstream in the plain of Monkayo (38%), and none in control area of Davao showed signs and symptoms of chronic mercury toxicity.

ENVIRONMENTAL AND HUMAN HEALTH EXPOSURE ASSESSMENT MONITORING OF COMMUNITIES NEAR THE ABANDONED MERCURY MINE IN THE PHILIPPINES (2002-2003) (Maramba, NPC *et al.*)

In a similar study conducted in 2002-2003, about 128 subjects consisted of 24 mother-child pairs and 19 pregnant mother-infant pairs from the study sites and 12 mother-child pairs and 9 pregnant mother-infant pairs from control sites were examined. The levels of total mercury in air, water and soil and mercury levels in fish in the exposed communities were significantly higher compared with the control.

The exposed children were found to have significantly higher blood total and methyl mercury levels and hair total and methyl mercury values. On the other hand, the mothers from the study sites showed significantly higher hair total and methyl mercury levels compared with the control.

Furthermore, the developmental status of the children born near the area was monitored using the Denver developmental screening test in as early as 6 months of age. The Denver Developmental Screening Test (DDST) II and Screening Behavioral Inventory (SBI) among infants and children showed persistent abnormalities in the personal/social, fine motor and language parameters among the exposed populations as compared to the control groups. The exposed children and infants demonstrated low scores in DDST II and SBI parameters as early as 6 months of age, particularly in fine motor, gross motor, personal/social and language domains that have significant correlation with their mercury levels.

MAJOR TOXICOLOGIC CONCERNS

As previously mentioned, it remains a challenge to establish the exposure situation such as the chronicity, the concentrations of substances, the frequency, and the route of entry of the toxic substances. More so, the chemical and physical properties of the toxic substances in the environment need to be established as well. Most of the time, the concern involves multiple metals or chemical substances and not just a single type. For example, in the case of the Marinduque incident, the substance of concern was not limited to lead alone but other substances such as arsenic and zinc were also involved. In Bulacan, there were about nine toxic metal substances that were involved. Thus, it is important to describe how these multiple toxic substances interact with each other and how do they produce the adverse effects in affected individuals.

Also included in the major toxicologic concerns are the individual factors such as individual susceptibility of both the old and the young ones, of the pregnant women, and the vulnerabilities of the other members of a community from toxic substances released in the environment as pollutants. Coupled with these concerns is the possibility of misdiagnosis of affected individuals. As mentioned earlier, a number of the adverse effects of toxic pollutants mimic some of the naturally occurring illnesses. Another challenge is the establishment of proper markers of exposure. A number of companies and institutions in the country dealing with environmental pollutions have already conducted documentation of some of the cases of exposure to toxic pollutants, but so far they were very limited to be considered as appropriate markers of exposure.

The methods of remediating toxic pollutants in the environment—including the advantages and the disadvantages of each method, remain as a challenge to scientists and researchers engaged in clean-up efforts. As in the case of mine tailings-contaminated river in Mogpog, Marinduque, the question would be how to remediate the toxic pollutants in such an environment.

STRATEGIES IN MANAGEMENT

Various strategies in managing the concern in toxic pollutants released in the environment can be devised and adopted. Firstly, regulatory safeguards must be put in place and be put into practice. The researchers and scientists in the field must have a concerted effort in advocating and lobbying policies and safeguards with regard to this concern. Crucial support from legislators must be gained by those concerned. Despite the availability of local expertise and technologies in dealing with toxic pollutants, without the support of the local government units, the success of implementing these safeguards and guidelines might not be fully realized. The knowledge gained and the technology developed in dealing with these toxic pollutants in the environment might only end up in literatures and get mothballed.

It is acknowledged, on the other hand, that our society has already good laws governing these concerns (e.g. Clean Air Act, Clean Water Act, Solid Waste Management Act). But what might be lacking are the awareness and the translation of these laws into practice. Aside from the above-mentioned safeguards, risk-reduction interventions, such as various remediation technologies and practices, can be employed when dealing with toxic pollutants.

The concern of the medical practitioners is to develop health surveillance, monitoring and treatment protocols. To be able to treat early on in time the long term effects of exposure to toxic pollutants, early detection and timely medical intervention are crucial. Thus, there is a need to come up with very good health monitoring and surveillance system and treatment protocols. In all of these, education and advocacies would always be important.

Three E's would indeed be vital in these strategies: Engineering, Education, and Enforcement. Engineers would be involved in developing technologies and methods in remediating pollutions in general. Educators, of course, would play important roles in upgrading public knowledge regarding these toxic pollutants and their adverse effects and advocating the use of sound technologies. Enforcement is very crucial in realizing the success of putting into practice the laws and safeguards already established.

RELATIONSHIP OF EXTERNAL EXPOSURE, INTERNAL EXPOSURE AND ADVERSE EFFECTS

To be able to prevent the adverse effects of exposure to toxic pollutants, a very good measure of external exposure must be available which also aids in environmental monitoring system. To be able to do this, appropriate research and diagnostic laboratories must be established. These laboratories are also vital in predicting adverse effects of toxic pollutants and in determining appropriate interventions and prevention measures for the ones affected. In addition, health surveillance, or the biological monitoring of effects, is crucial for early detection of the adverse effects of toxic pollutants.

The internal dose measurement, as determined by biological monitoring of exposure, remains a challenge to medical practitioners and toxicologists due to lack of established biological markers. Biological monitoring of exposure is important in preventing the onset of adverse effects due to exposure.

THE DPSEEA FRAMEWORK

The DPSEEA Framework is established by the partnership of the World Health Organization (WHO), UNEP, and the HELI in 2004. This framework describes the important factors such driving forces (e.g. economy, politics, society and various government and non-government institutions) that influences decision-making processes with regard to health and environmental programs, and the various environmental pressures (e.g. resource depletion, waste release in the environment, etc.) that lead to the promotion of sustainable and equitable patterns of production and consumption. Furthermore, looking on the current state of the environment (e.g. degraded ecosystem, services available, pollution, etc.), there is a need for capacity building in monitoring and managing wastes and resources.

In addition, the health sector is mainly concerned with the monitoring of exposure and susceptibility of the general population to pollutions and infections. It is also the concern of the health sector to improve personal protection from pollutions and infections and to provide the necessary medical interventions (treatment or rehabilitation) in cases of exposure to minimize its adverse effects in terms of morbidity or mortality.

SOME TAKE HOME POINTS

- In addressing environmental pollution, it is important to consider sequence of events from pollutant source to health effects.
- Toxic responses to chemicals are dependent on the intrinsic properties of the agent, the exposure and individual factors.
- Health effects can either be acute or chronic and may involve multiple organ systems.
- Acute effects of chemicals are different from their chronic effects.
- Major concerns in addressing toxic exposures are chronicity of effects, chemical interactions, individual vulnerabilities and remediation goals, and;
- Strategies in management involve engineering controls, public education and policy enforcement.

"Man has lost the capacity to foresee and to forestall. He will end by destroying the earth."

- Albert Schweitzer

HUMAN ECOLOGICAL IMPERATIVES OF BIOREMEDIATION FOR TOXIC MATERIAL POLLUTION

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ABSTRACT

Bioremediation is not yet widely accepted by policy makers and parties responsible for the management of environmental pollution. The paper premises that this is largely due to the absence or insufficiency of the imperatives to make bioremediation a viable option for the solution of environmental pollution. The paper briefly discusses human ecological security as a framework for bioremediation, then expounds on vital components for bioremediation as a response to pollution management from a human ecological perspective. It discusses suggested parameters of human ecological security in relation to bioremediation as a technological response to pollution mitigation. These include social justice, environmental integrity, institutional support, economic viability, and social acceptability. It presents ideas and initial definitions of these imperatives from various interest groups.

Through the conduct of key informant interviews using three bioremediation pilot tests as focus of discussions, the paper maps out the interaction between and among different interest groups involved in the bioremediation pilot testing. The analysis of these interactions generate initial issues pertaining to the identified imperatives. As part of its recommendations, the paper calls for more participatory methods in identifying ethical and social issues in bioremediation technology development and the conduct of social and collaborative researches in each of the bioremediation imperatives. It also recommends an institutional support framework to realize these imperatives.

Key words: human ecological security, bioremediation, human ecological imperatives

INTRODUCTION

This paper contends that as far as the Philippines is concerned, bioremediation still has to be widely accepted and advocated for clear mainstreaming by policy makers and parties responsible for the management of environmental pollution. This is largely due to the absence or insufficiency of the imperatives to make bioremediation a viable option for the solution of environmental pollution. The development of bioremediation as an option either to serve the purpose of pollution remediation or prevention, rests on meeting these imperatives. Addressing these imperatives starts with identifying them; the second phase is equally important but more rigorous though: that of studying the components of these imperatives. Each of these imperatives contain a rich field of researchable areas, where collaborative and integrated work can be done to facilitate the social, economic and cultural viability of bioremediation for heavy metals pollution management.

To systematically identify these imperatives, the paper suggests a framework based on human ecology, contending that such a framework has the ability to cover the concerns which spans the more technical issues to the more social and economic tight spots. However, there are also other questions accompanying the effort of identifying and defining these imperatives. One falls under the debate of whether there is a indeed a need for including bioremediation in our menu for pollution management. This question is largely important in making bioremediation research meaningful, but might not be fully answered by this paper. The framework suggested in this paper, however, may partly provide a guide for us to eventually answer it.

The main objective of this paper is to put forward the participation of social science research in bioremediation for toxic material pollution management along the theme of human ecological imperatives of bioremediation. Specifically, it aims to 1) present a human ecological perspective for bioremediation as an option for heavy metal pollution management; 2) identify representative factors of the human ecological imperatives; and, 3) to generate recommendations to address the imperatives for bioremediation.

HUMAN ECOLOGY AND HUMAN ECOLOGICAL SECURITY AS A FRAMEWORK FOR BIOREMEDIATION

Regardless of how one views it, Human Ecology is young. As such, there are lots of debates going on as to the its definition, its coverage, and the directions it can take. To date, there is no consensus whether human ecology is a discipline, a conceptual framework, or a set of principles (Lawrence, 2009). The usual reference to it is as "study of the dynamic, systemic relationships between human populations and the physical, biotic, cultural and social characteristics of their environment and the biosphere" (Young, 1983). To the likes of Roderick Lawrence (2005), however, what is explicitly clear about human ecology is that it is anthropocentric. Its study of human ecosystems in contrast to non-human ecosystems is considered as its distinguishing character. In this regard, humans are viewed not just as biological organisms with a genetic code, but also as individuals with social and cultural characteristics that distinguishes them from other species. This is the very reason that for purposes of disciplinal categories, human ecology has been classified as a social science. But because it is anchored on the basic idea of a systemic interaction between humans and the entirety of their environment, human ecology cannot discuss social issues apart from the concerns of the natural sciences. A research and analytical framework rooted in human ecology is therefore one that will always reflect the academic and practical considerations of the natural sciences and the social sciences.

With such a framework, the tendency to separate the study of natural ecosystems from the social system—or the human part is eliminated. The human ecosystem framework discussed by Machlis et al. (1997) is saying that to be able to capture necessary factors as in studying social actors, individual or as groups and institutions engaging with the critical resources making up their environment, it is best to look at human beings as part of a more encompassing system rather than compartmentalizing them apart from natural ecosystems (Figure 1).

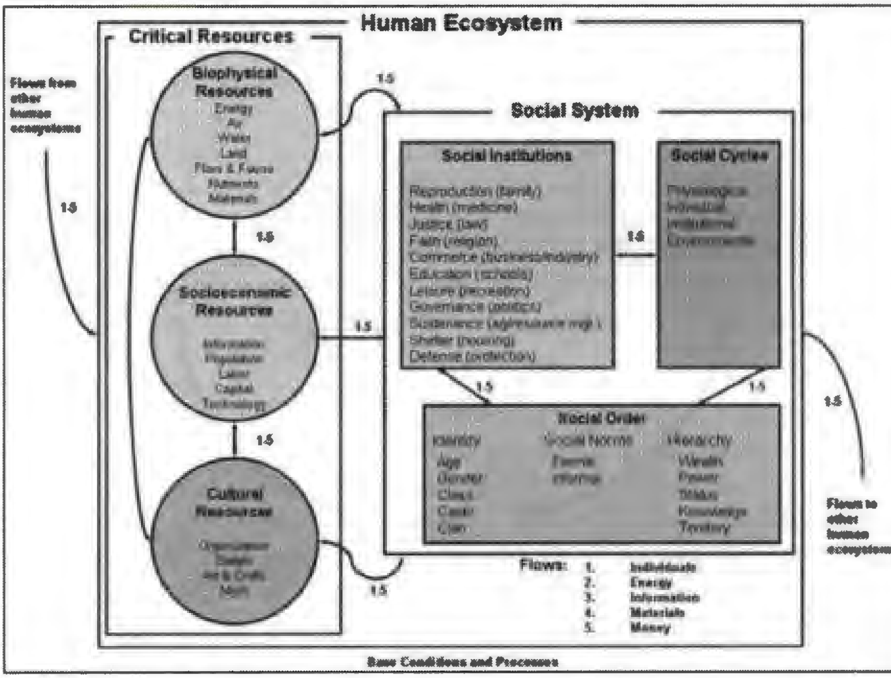

Figure 1. The Human Ecosystem Framework (Machlis, Force and Dalton, 1997)

Given this, the concept of human ecological security is recommended to provide the framework in identifying the imperatives or the necessities for the mainstreaming of bioremediation as a response to environmental pollution. For this purpose, human ecological security is defined and anchored on the principle of sustainable development. In the context of assessing the viability of bioremediation both as an approach and as a set of technology for pollution technology, this translates to long-term safety for functional human ecosystems. We want to see fully functional human ecosystems where the current needs of human populations are met by environmental services without undermining the integrity of the environment to continue its services for the next generation. Any technology that results from the need to sustain the symbiotic relationships between and among the components of a human ecosystem must thus answer to this basic principle of human ecological security. In the long-term, it must be within the measures of human ecological sustainability. A schematic diagram of a human ecology that will be responsive to the Philippine context as suggested by the College of Human Ecology of UP Los Baños is an initial supposition to this end (Figure 2).

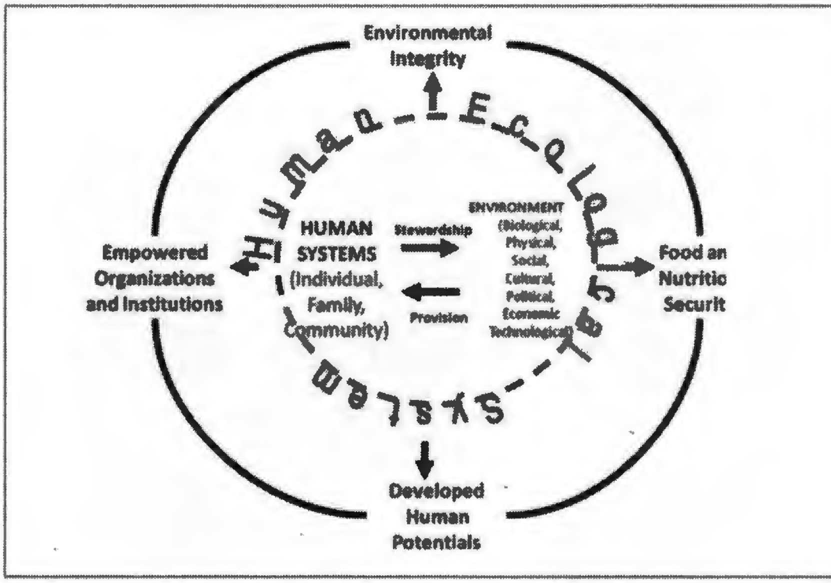

Figure 2. Conceptual Framework of Human Ecology (CHE, UPLB, 2008)

The diagram posits that any sustainable and secured human ecosystem is characterized at the minimum by four broad areas of imperatives: 1) its operation contributes to environmental integrity, 2) it responds to food security and safety concerns, 3) it provides opportunities for the development of full human potentials across the lifespan and across societal sectors; and, 4) it contains strong and capacitated social institutions capable of regulatory, facilitating and integrating functions as the flow of energy, materials and critical resources take place within the system. This last category of imperatives is further qualified with adherence to principles of social justice and social participation. Our basic question for bioremediation for environmental pollution as a practical and technological application of scientific knowledge is thus: what are the human ecological imperatives bioremediation must address?

IMPERATIVES OF HUMAN ECOLOGICAL SECURITY IN RELATION TO BIOREMEDIATION

The insights generated in relating bioremediation to issues of human ecological security were product of key informant interviews of eight researchers. Discussions with them were especially helpful in identifying various stakeholders in the area of bioremediation. Bioremediation as the use of micro-organisms and plants to detect, degrade or remove environmental pollutants from soil, water or air sets into motion scientific research into various bioremediation technologies. In biology and chemistry parlance, these may include among others: 1) the use of bacteria to detect pollution, or biosensors; 2) the use of plants to degrade or sequester pollutants, or phytoremediation; and 3) the use of micro-organisms to degrade pollutants as in the case of bioaugmentation. However, together with the excitement that can characterize bioremediation scientific research, bioremediation is a phenomenon that also potentially raises a number of social, economic, development and ethical issues. These issues will grow in number and gravity as scientific knowledge and advances in bioremediation technology continue to develop. Among these issues are the following:

1. Social justice

From a social development perspective within the broader frame of human ecological security, social justice is necessarily concerned with equal justice, not just in the courts, but in all aspects of society. This demands that people have equal rights and opportunities; everyone, from the poorest person on the margins of society to the wealthiest deserves an even playing field. So as to promote full human ecological security, social justice must be addressed within two dimensions: intragenerational social justice , and intergenerational social justice. An even playing field for instance means that no sector of our current generation is going to be marginalized by any promotion and eventual utility of bioremediation; equally important is ensuring that this absence of marginalization will continue to be true for subsequent generations.

In addition to the generational dimension, social justice can come in several expressions depending on the interest group mulling over it. Geographers, for instance, may be concerned with the spatial expression of social justice; where do advantaged and disadvantaged groups live, why they live there, and what is the connection between their place of residence and their future advantage or disadvantage (Harvey 1996; Smith 1994, 2000). On the other hand, service providers as an interest group or stakeholder of bioremediation may define social justice within the bounds of equity of business opportunities / equitable trading system, while those representing the environment may bring forth the issue of bioremediation effect on biodiversity of biotic populations. It becomes clear that an integral response to social justice as a bioremediation imperative is the stakeholders analysis of the phenomenon. Stakeholders analysis is important in two basic ways as far as social justice is concerned: 1) so as to systematically identify who composes the interest groups of bioremediation, and 2) so as to have a basis of eventual consensus building around the principle of social justice that should characterize a national agenda for bioremediation. Needless to say, this is one area of action research waiting for the social scientists among us.

It is also an area which necessarily espouses more participatory methods both in research and action programs.

For example, despite the problems encountered in organizing and mobilizing these various groups, the establishment of the Marilao-Meycauayan-Obando River System (MMORS) stakeholder groups (Figure 3) as part of the Clean the MMORS Project provided people the chance to sit together and discuss the problems besetting the MMORS, and examine options they can take to improve their community and their local government units (LGUs). With a sustained effort to achieve project goals and adhere to the principle and utility of the participatory approach, the stakeholder group eventually spun-off into a formal Water Quality Management Area (WQMA) with a supervising Board in accordance with RA 9275 otherwise known as the Clean Water Act of 2008.

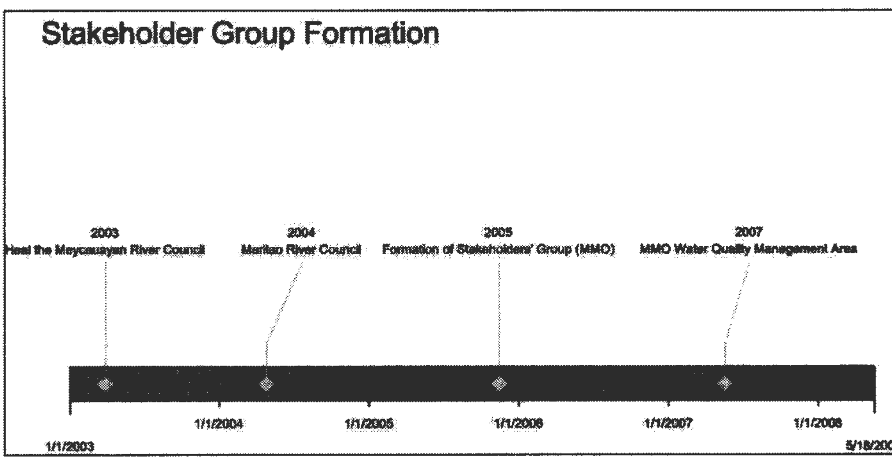

Figure 3. Establishing various MMORS stakeholder groups.

In a study of stakeholders of the project, stakeholder groups identified included the academe, government agencies and affected LGUs, the private sector as represented by the major industry players affecting the MMO River System, civil society as represented by church- and people- organizations as well as non-profit organizations, and the media. The analysis showed that each of the identified stakeholders vary in their interests and the crucial roles they play in the project. Highlighted was the role of the academe in providing project directions through empirical research, the legitimizing role of government line agencies as well as those of LGUs, the dual role of NGOs in providing the moral impetus for environmental clean-up and networking for fund-raising, and the pressure created by media exposure (Mendoza et al., 2009).

In the case of bioremediation, identifying the various stakeholders and the definition of their roles can eventually lead to a consolidation of their particular notion of social justice that is supposed to be characterizing bioremediation. Clarifying how bioremediation science and technology adheres to, and can promote social justice will bring the bioremediation agenda more and more into the mainstream of pollution management.

2. Environmental integrity

At its most basic, environmental integrity refers to the ability of an ecosystem to sustain the important biophysical processes which support plant and animal life. Its objective is to ensure the continued health of essential life support systems of nature, including air, water and soil, by protecting the resilience, diversity, and purity of natural communities or ecosystems within the environment. When we consider bioremediation as a means to address damaged ecosystems in the short term, we must also ensure that its technologies do not undermine the long term integrity of our natural ecosystems, and concomitantly, the integrity of human-environment interaction. This is enough rationale to conduct research to evaluate the life cycles of bioremediation technologies. Apparently, this is easier said than done. According to interviews with researchers in the field of bioremediation, there are many twists and turns causing a high degree of uncertainty in determining the success for instance of the use of microbes to degrade polychlorinated biphenyl (PCB) in contaminated soils or sludges. This uncertainty was also documented in the report of a pilot test of PCB bioremediation in the former Clark Air Force Base (Blacksmith, 2010). Such difficulty in this research area must not deter the impetus to provide scientific knowledge about the nature of bioremediation which has implications on the maintenance of environmental integrity.

There is also a need for long term human ecological research in the area of bioremediation. In the light of uncertainties, especially in the area of biosafety, the scientific research agenda must go beyond the studying the life cycle of microbes for instance in a pilot test. There will be a need to conduct long-term human health impact of bioremediation technologies. Longitudinal research which may utilize social surveys among others, will be called for. Getting ready to consider bioremediation as a viable option in pollution management means getting ready to conduct these researches.

As it is with social justice, environmental integrity as an imperative for bioremediation involves a number of interest groups which includes but is not limited to government agencies. These various groups would have their own concept or definition of environmental integrity, which must be put in place for the furtherance and sustainability of bioremediation as an option.

3. Organizational and institutional support

Human ecological security cannot be achieved without strong organizational and institutional support. Establishing and capacitating the stakeholder groups is one of the imperatives for bioremediation. In capacitating the stakeholder groups, the groups' financial and social capital must be enlarged. A single stakeholder group cannot do everything with regard to pushing for bioremediation. Collaborative effort among the various stakeholders is needed to craft a clear and strategic advocacy to put bioremediation in the priority agenda of science and technology (S&T) development. Partnerships must, therefore, enhanced. Corollary to this, capacities of individual stakeholder groups must be developed. The goal is towards consensus building in crafting the policy agenda and direction for bioremediation in the country.

Part of the organizational and institutional support would be putting in place policy agenda. This implies the need for policy reviews and analyses, and development of guidelines and standards for bioremediation. Another part of this support would be establishing new, if none at all, or strengthening, if there are already, organizational arrangements for the purpose of defining or refining the national bioremediation agenda framework. There is also a need to facilitate access of end-users to existing technologies, consolidate and integrate current and continuing efforts for convergence, and to push for an integrated, multi- and inter-disciplinary bioremediation research and development agenda.

4. Economic Viability

For bioremediation to work, studies are needed to show a comparison of the cost and efficacy of various bioremediation technologies. It is not enough to just consider the cost of the bioremediation technology; viability also importantly requires consideration of the full cost in ensuring the efficacy and sustainability of bioremediation. Cost-effectiveness consideration includes the cost of setting up, operations and maintenance of a technology or facility, its efficacy, and even exigencies arising from the use of the technology. The success of mainstreaming bioremediation as a viable option for pollution management will also depend on its comparative economic value vis-à-vis the value of other existing options given specific cases of pollution problems, not only in terms of actual costs but also in terms of the social, environmental and economic impact of choosing bioremediation over other approaches and methods. Putting bioremediation in the forefront of our national S&T agenda will need to take all these into consideration.

5. Social Acceptability

Social acceptability as an imperative for bioremediation looks into the social acceptance and the intention to use a technology. Just like any relatively new branch of scientific knowledge, the public intention to adopt bioremediation technologies will be heavily dependent on a number of factors including real as well as perceived safety and other risks entailing its adoption, its economics, its consistency with existing cultural practices and beliefs, and the effectiveness of its advocacy, education, communication and social mobilization package (Mallet, 2007).

The indicators that are needed to consider would be the knowledge of the people about bioremediation, their perceptions, and their attitude or feelings towards certain bioremediation technologies (including fear associated with it). These indicators are avenues for more innovative and participatory advocacy, education and mobilization strategies.

The research imperatives in bioremediation with respect to social acceptability may include the knowledge, attitude and intentions of various stakeholder groups, the efficacy of social technologies, and new ways of consensus building. The future of bioremediation to contribute to pollution management is thus heavily dependent on the ability of the scientific community and other stakeholder groups to embrace principles of social marketing, and their capacity to get their acts together. This is especially crucial due to the complexity and breath of possible bioremediation technology, and its social system context wherein other environmental management options are available and where institutional as well as political agenda play significant roles.

Among the significant stakeholders mentioned by researchers are: 1) the local government units (LGUs) who can play important roles in technology and policy adoption and regulation; 2) government line agencies as regulatory and research and development bodies; 3) local communities who will be adopting the bioremediation technologies and policies; 4) service providers who will be responsible in marketing, reporting and disclosure of research and development of bioremediation technologies; 5) the academe which is mainly responsible for knowledge and technology generation through research and development; and 6) the local environment which is the recipient of these technologies. All these players need to come together to define the nature of the various imperatives considering their varied interests and stakes, as well as to critically discuss how these various imperatives can be achieved.

CONCLUSION AND RECOMMENDATIONS

The imperatives discussed in the paper is in no way complete. Most of those discussed fall under institutional strength and environmental integrity dimensions. Much has to be said with regards to the response and niche of bioremediation in ensuring food security and safety, as well as its potentials in promoting the development of human well-being across the lifespan and across various levels of social life. It is, however, clear that a human ecological framework provides an encompassing analytical basis for assessing what needs to be put in place to secure a clear niche for bioremediation in pollution management. In the same light, it is able to highlight research agenda to support this advocacy for bioremediation.

In the light of the above human ecological framework and imperatives discussed, it is recommended that, 1) participatory methods be employed in the following undertaking:

- Identifying ethical and social issues in bioremediation technology development;
- Crafting a strategy for the continuous mainstreaming of bioremediation;

2) priority be given to the conduct of social and collaborative researches in each of the bioremediation imperatives; and, 3) clear and sustained efforts be focused on strengthening and/or establishing institutional arrangements to support and realize the imperatives.

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ABSTRACTS OF ORAL PAPER PRESENTATIONS

BIOREMEDIATION OF INDUSTRIAL AND AGRICULTURAL TOXIC MATERIALS

NICKEL UPTAKE AND SOIL MICROBIAL ACTIVITY OF *Brassica juncea* (INDIAN MUSTARD) AND *Zea mays* (CORN) GROWN IN NICKELIFEROUS LATERITE FROM PALAWAN, PHILIPPINES

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One of the environmental problems the Philippines is facing is the heavy metal contamination of the soil. In the search for solutions, this study looked into the nickel uptake of *Brassica juncea* and *Zea mays* that were grown in nickeliferous laterite. The study also determined the ability of the rhizosphere microbial consortium obtained from both plants to precipitate the nickel in solution.

Plant growth responses were evaluated by determining the percent differences in the length of the shoot and root, growth rate, dry matter production and water content. The phytoextraction capacities of the plants were established through their Bioconcentration Factor (BCF) and phytoextraction rates. The bacterial consortium from the rhizosphere of the plants were used to determine the ability of bacteria through the resulting bacterial inoculants in precipitating nickel in solution and this was monitored

for 7 days. The amount of nickel present was analyzed using Atomic Absorption Spectrophotometry. Results reveal that there was an increase in Ni concentration in the plants growing in soils with correspondingly high Ni concentration. Based on the BCF values, *Zea mays* shown medium Ni accumulation while Brassica juncea showed slight Ni accumulation. The enriched bacterial consortiums taken from *Zea mays* and *Brassica juncea* reduced the nickel concentration in the solution to about 75-80%.

The effects of nickel toxicity were observed in *Brassica juncea* and these included wilting, chlorosis and stunted growth. Stunted growth in *Zea mays* was also noted. The use of compost helped lessen the nickel toxicity in *Brassica juncea* though no visible effects were observed in *Zea mays*.

BIOREMEDIATION THROUGH SELECTIVE RECOVERY OF HEAVY METALS FROM INDUSTRIAL WASTEWATER USING BIOGENIC HYDROGEN SULFIDE (H_2S)

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The case of the Marilao-Meycauayan-Obando (MMO) River System in Bulacan is quite unique because there are industries upstream utilizing toxic heavy metals and substances that eventually find their way to thousands of hectares of thriving aquaculture industry downstream. The tannery and gold smelting industries are the most organized among the different sectors and are thus, more willing to collaborate in this research project. They have come to realize that unless immediate characterization and necessary interventions are developed and carried out in their wastewaters, these ecologically fragile river systems will become some of the most unproductive freshwater source in the country.

The main objective of this study is to develop and apply a biotechnological intervention strategy for the remediation of heavy metal contaminated industrial wastewaters and develop/design a bioreactor system for the selective recovery of heavy metals using biogenic hydrogen sulphide. Sulfate-reducing bacteria (SRB) obtained from Bulacan, Philippines were screened for the production of H_2S to be used for the precipitation of copper and reduction of chromium from goldsmelting and tannery wastewater respectively. SRB culture designated as SRB-B15 showed 99.99% Cu^{2+} removal from metal-laden effluent with an initial concentration of 5000ppm. Application of H_2S treatment to chromium-laden wastewater showed that it is effective for simulated tannery wastewater with hexavalent chromium (in the form of Cr^{6+}). Promising preliminary results were also obtained for the removal of Pb^{2+} and Zn^{2+} from simulated wastewater.

In this study, a bench-scale bacterial sulphate reduction treatment system was designed and evaluated for the treatment of industrial wastewaters containing copper, chromium, lead and zinc. The performance goal for the treatment system is to produce an effluent having a neutral pH and containing less than 1.0 mg/L of any heavy metal. The treatment system is expected to recover a metal concentrate that could be processed at existing smelters for metal recovery. This study showed that biogenic H_2S technology is a promising biotechnological intervention strategy for the remediation of heavy metal-contaminated industrial wastewaters.

CO_2 PRODUCTION DURING BIOFILTRATION AT DIFFERENT SOIL MATRIC POTENTIALS

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Biofiltration is a pollution control technology where contaminants in a gas stream are degraded by microorganisms and converted to water, carbon dioxide, and biomass. In this study, a biofilter with internal gas recycle and a suction cell was used to investigate biofiltration performance at different matric potentials of the bed medium in the reactor using CO_2 production as a measure of the extent of biodegradation. Soil was used as the medium in the biofilter.

Water is essential for microbial growth/activity and for transport of nutrients. Water in soil and other porous media is mainly retained by matric forces in pores and matric potential is a measure of water availability. The matric potential was related to gravimetric water content through a water retention curve generated in the study.

A toluene-contaminated air, at an average flow rate of 21 ml/min and at an inlet concentration controlled between 240 and 350 ppm, was used in this study. The CO_2 production and the elimination capacity, which describes the amount of contaminant removed or treated, were monitored daily for about 6 months.

Results show that during drying of the soil, the CO_2 production varied directly with the elimination capacity but this was not observed during wetting. CO_2 production is therefore influenced by the matric potential of the soil and may be used as a measure of biodegradation during drying but not during wetting. This implies the need for caution in the use of CO_2 production as an indicator of biodegradation at varying matric potentials.

CAN MUSHROOMS BE USED FOR BIOREMEDIATION? UPTAKE OF METALS IN BASIDIOMYCETES GROWING IN SOIL ON RECLAIMED INDUSTRIAL SITES IN THE MELBOURNE REGION

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Heavy metal contamination of soils is a significant problem at sites with a mining or industrial land use history. Companies are obliged to rehabilitate such areas to improve aesthetics, soil structure, and minimise flow-on effects to surrounds. Mycoremediation aims to extract heavy metals from polluted soils using hyperaccumulating fungal fruiting bodies.

Fungal species particularly of the Phylum Basidiomycota have been shown to accumulate considerable concentrations of heavy metals from soil. Consequently, naturally occurring higher fungi on contaminated sites, especially in built-up urban areas, are possible contributors of heavy metal transfer through the food chain and could present a health risk to the public and other animal mycovores. Exposure to, or consumption of, heavy metals is known to cause serious damage to human health.

Fungal and soil samples were collected from 16 sites consisting of urban, industrial, mining, agricultural land uses and parkland. The most common fungi collected were species of *Agaricus* and *Scleroderma*. Genera such as *Amanita*, *Suillus* and *Xerula* were identified from sequence analysis of the rDNA ITS sequences. Soil from several sites were found to contain various trace elements, most notably cadmium and mercury. Basidiocarps of commonly occurring genera such as *Agaricus*, and *Coprinus* contained appreciable amounts of cadmium and mercury. Selected *Agaricus basidiocarps* accumulated up to 18 μg/g cadmium, 26 μg/g mercury and 60 μg/g lead. Mean Cd contents were above the statutory limit for wild-growing mushrooms of 2 μg/g, but average Hg and Pb concentrations were below limits of 5 μg/g and 10 μg/g, respectively. Among the most contaminated sites were urban areas, reclaimed industrial soil, a metropolitan park and a state park.

A RECOMBINANT LIPASE FROM *Geobacillus* sp., M_5 SHOWS POTENTIAL FOR LIPID WASTE DEGRADATION

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A local isolate, identified as *Geobacillus* sp., M5, from a hot spring in Albay was found to produce lipase with activity higher than other bacteria. In order to circumvent the high energy requirement for growth of M5 at 65°C, the 1.8kb lipase gene fragment from M5 was cloned into *E. coli*. Transformants expressing the enzyme exhibited fluorescence on Rhodamine B plates upon irradiation with UV light (350nm) and opalescent zones in $CaCl_2$ plates. The recombinant lipase had a specific activity one hundred (100) times higher than the crude native lipase, a molecular mass of 50 kDa and pH and temperature optima of 7 and 70-75°C, respectively.

The recombinant lipase was applied to various oils to determine its potential in industrial and environmental waste management applications. Cooking oil, virgin coconut oil (VCO), fast food oil waste and household oil waste were treated with recombinant lipase and the resulting fatty acids were determined by gas chromatography. Recombinant lipase showed preferential hydrolysis of C12 fatty acids in cooking oil and VCO while fast food and household waste oils were completely hydrolyzed. This result shows that the recombinant lipase has potential to degrade waste oils.

DEGRADATION OF CRUDE OIL AND UTILIZATION OF HYDROCARBON COMPOUNDS BY BACTERIAL ISOLATES FROM USED ENGINE OIL-CONTAMINATED SOIL AND DETECTION OF THE HYDROCARBON-DEGRADING GENES

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Two strains of *Gordonia terrae* were isolated from soil contaminated with engine oil using mineral salt medium (MSM). Initial identification using Biolog Microbial Identification System revealed the isolates as *Rhodococcus coprophilus* and *Gordonia rubropertinctus*. However, nucleotide sequences from amplified 16S ribosomal DNA (rDNA) and phylogenetic analysis showed that the two isolates (designated as G1 and G2) were two different strains of *Gordonia terrae*. The isolates are capable of degrading hydrocarbons specifically n-alkanes as demonstrated by HC utilization fingerprints and GC-MS experiments. They cannot, however, utilize polycyclic aromatic hydrocarbons as their sources of carbon and energy. Their capability to grow on a wide range of saturated hydrocarbons is attributed to the presence of the alkane hydroxylase gene (AlkB). However, PCR investigation revealed that the naphthalene catabolic gene (nah) did not coexist with the AlkB gene.

RENOVATING MILL EFFLUENT THROUGH FOREST IRRIGATION

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A Georgia Pacific (GP) Corporation pulp and paper mill located in Florida generates 35 million gallons of effluent everyday. Because the effluent has high salt index, its disposal requires a series of expensive biological and physical treatments and raises some serious environmental (air and water pollution) concerns. We hypothesized that (1) this voluminous waste can be converted into a resource, (2) soil (with millions of resident microorganisms) and forest trees can be used in effluent bio-remediation and (3) source of water pollution can be reduced if not eliminated. A large tract of forest land (12,000 acres) in the vicinity of the mill and a previously successful work by GP on fertigation (injecting nutrients in the irrigation system that produced phenomenal tree growth) provided strong justifications for testing these hypotheses.

The mill effluent was piped to a forest land to irrigate newly planted pine and hardwood trees using the sprinkler system and drip method. Fertilizer nutrients at varying levels were added to both irrigation methods. Monitoring wells were installed in strategic locations of the area to measure changes in groundwater quality.

Tree growth response varied with irrigation methods and tree species. Foliar damage, stunted growth and mortality were observed with some species under the sprinkler system while phenomenal growth was observed with trees receiving drip irrigation. Water samples from the monitoring wells did show elevated salt contents in the groundwater predominantly under the sprinkler system but under drip irrigation where rapid tree growth occurred, the salt content increase was minimal, indicating that evapotranspirational pull exerted by the growing trees had extracted the salt components from the groundwater. This study clearly showed that proper utilization of mill effluent can enhance forest productivity and reduce the volume of waste water being dumped into the waterways, consequently reducing a point source of water pollution and demonstrated that soil (with microorganisms) and growing trees can be effectively utilized in the process of mill effluent bioremediation.

A BIOREMEDIATION TREATMENT OF TANNERY WASTE WATER BY CHELSI LEATHER & SERVICES

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Leather tanning has been one of the oldest crafts or industries in the world as it not only serves ancient man's necessity for clothes and shelter but offers the modern world a wide range of merchandise from footwear, fashion, automotives and furniture. But as the demand for leather increases, tanners in the Philippines are now facing problems in dealing with wastewater associated with mass production of leather. Chromium trivalent is currently the widely used tanning agent in leather. But chromium in its hexavalent form is considered highly toxic and carcinogenic. Aside from this, high levels of COD, BOD, TSS, grease and oil are also present in the waste water.

Separation of chrome-laden wastewater from the bulk of the wastewater is one of the steps that Chelsi Leather & Services has initiated to address this problem. This was treated by alkali to precipitate out the metal from solution. The bulk of the wastewater is subjected to biological treatment where it is converted into clean water, gas, and organic sludge. Water is then returned for reuse to a receiving stream, the gas to the atmosphere, and the digested sludge to the sludge drying bed as a low grade conditioner. Wastewater from the tannery that was collected and analyzed before and after treatment indicated successful reduction in the chrome trivalent and chrome hexavalent concentration. Lower levels of COD, BOD and TSS were also achieved in compliance to the standards of the DENR.

BIOREMEDIATION IN AQUATIC ECOSYSTEMS

CAPABILITY OF MICROALGAE (*Chlorococcum* sp.) AND MACROALGAE (*Sargassum* sp.) TO REMOVE HEAVY METAL (CR AND CU) FROM SYNTHETIC WASTEWATERS

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The performance of *Sargassum* sp., laboratory-cultivated *Chlorococcum humicola.* and commercial granulated activated carbon (GAC) for copper (Cu) and chromium (Cr) removal from aqueous solutions was evaluated in this study. Kinetic and isotherm batch experiments were done at pH 4.5 + 0.1 for Cu (II) and 2.0 + 0.1 for Cr (total). The equilibrium isotherms were determined and the results analyzed using Langmuir and Freundlich models. The adsorbents were capable of sequestering appreciable amounts of Cu, although significant difference in their performance was observed. Best Cu removal performance was observed on *Sargassum* at 87.3% maximum removal obtained for an initial concentration of 20 mg L^{-1} Cu. The maximum uptake capacities for Cu (II) were 71.4 mg g^{-1}, 19.3 mg g^{-1} and 11.4 mg g^{-1} of *Sargassum*, *C. humicola* and GAC respectively. The adsorbents were also able to remove appreciable Cr amounts but not as high as copper removed. Chromium maximum uptake capacities were 8.5 mg g-1, 5.7 mg g-1 and 4.3 mg g-1 of *Sargassum*, GAC and *C. humicola* respectively. Kinetic studies

reveal that copper removal rate is much faster than of chromium. Experiments with copper showed that equilibrium was attained at around 1.5 h while it took about 6 h for chromium to attain equilibrium. Pseudo-second-order rate model best describes the metal uptake of the materials. *Sargassum* has the best potential for copper removal and may be used as a low-cost alternative to more conventional biosorbent materials.

THE PHYSICO-CHEMICAL EFFECTS OF THE APPLICATION OF PHYTOREMEDIATION IN A POLLUTED CREEK AND HOW TO BRING ABOUT A COMMUNITY-BASED MANAGEMENT OF POLLUTION FOR ITS CONTINUING RESTORATION

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A study was done to explore the efffects of installing a macrophyte biosorption system (AMBS) across the Molawin Creek, and based on the results carry out the initial steps towards a sustained community-based restoration, protection and conservation program for this body of water.

Initally, the baseline physico-chemical conditions in the creek were established in terms of total Kjeldahl nitrogen (TKN), soluble reactive phosphorus (SRP), total phosphorus (TP), BOD, and COD measured in six different parts of the creek. The sampling stations were Sta. 1, UPLB Hortorium; Sta. 2, UPLB Student Union; Sta. 3, above sewage outfall No. 1; Sta. 4, below sewage outfall No. 1; Sta. 5 after the STCJP outfall; and Sta. 6, Sitio Riverside. The water quality effects of the two AMBS located in two diffferent parts of the stream about 800 m apart were evaluated based on the results of comparison of the observed levels in the stream water before and after passing through the system.

The baseline data indicated two out of six sampling stations as having acceptable water quality based on COD, namely, Sta. 1 and Sta. 2. Impairment of water quality occured in the rest of the stations, based on the very high levels of COD. Nitrogen and phosphorus levels were indicative of eutrophication. The most polluted was Sta. 6 or Sitio Riverside where people use the stream up to the present for bathing, washing and kitchen water. Fishes were very scanty in the stream and no individuals were spotted within the next 10-m stretch downstream from the outfall.

Stream water that passed through the two AMBS was found to have a high but widely varying % reduction in the levels of alkalinity (0.6 - 24%), COD (33 - 64%), TKN (4 - 30%) and TP (2.5 - 9%). Both set -ups increased Cd by 2-9%, decreased Pb by ~ 7%; but had inconsistent results on Fe levels. The most remarkable effect of the AMBS was the proliferation of fingerlings in the creek.

Because of the encouraging effects of the AMBS, and the possibility of further increasing its efficiency through use of other native plant species, it was recommended to the chancellor of UPLB that the creek be declared a biopark so as to sustain the efforts of restoring, protecting and conserving its resources and protecting Laguna de Bay from pollution. Now the creek is known as the Molawin BioPark. Since its declaration as such, the biopark has been publicized, and presently, there are six organizations that have joined hands with the UPLB Occupational Health and Safety Standards Committee that is leading in the stewardship of the Molawin BioPark. The rest of the paper deals with the actions done to encourage community stewardship of the Molawin BioPark.

GIS-AIDED SUITABILITY INDEX FOR FISHPOND OF INTEGRATED LIVESTOCK-AQUA FISHERFOLKS IN PAMPANGA

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To generate a comprehensive and reliable basis for finding suitable fishpond locations that would not compromise production and profit among fisher folks, the fishpond suitability index (FSI) for integrated livestock-fish farming using Geographical Information System (GIS) software ArcGIS version 8.2, developed by Environmental Systems Research Institute, was utilized. In plotting the FSI, factors related to technical parameter and eventually profitability of fishpond operation were considered. The different factors utilized to determine suitable fishpond sites were plotted into eleven thematic maps and are enumerated as follows: slope, soil type, flood risk, land use, distance to irrigation canal, water sources, roads, market, hatchery, agricultural supplies and poultry and livestock farms. The cartographic model for determining suitability areas for fishpond and the suitability map developed by the project team matched CHED Center of Excellence for Agricultural Education, Central Luzon State University, Science City of Munoz, Nueva Ecija with the existing fishpond sites in the area thereby confirming the efficacy of the model, however, appropriate simulation models that should be tested for accuracy following reliable scientific equations should be done in future investigation. Finally, the above suitability maps for fishponds in Pampanga can be replicated nationwide with due consideration to management related interventions recommended by the project team.

BACTERIAL MERCURY RESISTANCE: DISTINGUISHING NATURALLY RESISTANT STRAINS FROM NON-RESISTANT

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A number of mechanisms have been elucidated for mercury metabolism in bacteria. Genetic potential is of primary importance and is the subject of intense research to enhance bacterial capacity to tolerate extremely high concentrations of this heavy metal as a future tool for bioremediation. However, most academe-based laboratories in the Philippines are still not equipped for any work at the molecular genetics level. Thus, there is a heavy reliance on phenotypic characterization of bacteria in searching for potential strains for bioremediation.

The primary objective of this work is to demonstrate how phenotypic characterization can be used as a reliable method in isolating truly mercury-resistant bacteria from the environment. A comparative study was done on the relative resistance of effluent- and non-effluent derived bacterial isolates grown in mercury (Hg^{2+})-supplemented MS agar plates, with concentrations ranging from 10 ppm to 40 ppm. Four effluent-derived bacterial isolates, namely, *Bacillus* sp., *Corynebacterium* sp., *Cytophaga* sp., and *Klebsiella* sp. tolerated mercury concentrations of 30 ppm to 40 ppm. Non-effluent derived strains, namely, *Proteus vulgaris*, *Bacillus subtilis*, *Bacillus cereus*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*, tolerated a maximum concentration of only 20 ppm of mercury.

There may be a need to refine what used to be considered as threshold for a truly mercury-resistant bacterial strain based on the results of this study. In the past, bacteria that can grow at mercury concentrations above 10 ppm are automatically considered as resistant. It is proposed in this paper that the resistance level be increased to at least 30 ppm for a strain to be considered resistant because all non-effluent derived bacteria used in this study grew at mercury concentrations of up to 20 ppm. This should increase the chances of isolating truly mercury-resistant bacteria from the environment for biotechnological application, such as in bioremediation.

BIOREMEDIATION OF MINE WASTES

SOIL BACTERIA AS INDICATOR OF PHYTOREMEDIATION EFFORTS IN AN ABANDONED MINE SITE IN MOGPOG, MARINDUQUE AND AS POTENTIAL BIOREMEDIATION AGENTS

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This study was conducted in conjunction with a phytoremediation experiment in an abandoned copper mine in Mogpog, Marinduque using several reforestation plant species. To determine the correlation between population of metal-resistant rhizosphere bacteria, known to promote development of host plant in contaminated soils, and growth of narra, the number of this group of microorganisms was analyzed and the plant growth was measured in terms of stem diameter periodically for a period of 12 months. Representatives of the rhizosphere bacterial population, as well as those from mine soil samples without vegetation, were also isolated, assayed for biofilm formation and identified in order to survey for species that can be used for future bioremediation applications.

The number of metal-resistant rhizosphere bacteria generally increased through time as narra got established in the environment. This trend was more pronounced with the Cd-resistant population. The Pb-, Zn- and Cu-resistant populations, on the other hand, showed varying counts through time. Furthermore, the metal-resistant rhizosphere bacterial population showed apparent positive correlation with the growth of narra when planted with jatropha and anchoan dilau only, while inverse correlation with growth when banaba was added to the mix. These results suggest that the growth-promoting rhizosphere bacterial population of potential phytoremediators like narra could serve as indicator of the rehabilitation effort in the heavy metal-contaminated environment of the abandoned mine site since the success of phytoremediation relies heavily on the effective establishment and growth of the plants on site.

Out of 60 heavy metal-resistant bacterial cultures isolated from the narra rhizosphere and soil without vegetation from the site, four demonstrated the ability to form biofilm in microtiter plates All have potentials as agents of bioremediation because of their resistance to heavy metals and ability to form exopolymers that can adsorb the pollutant from their environment.

THE DISCOVERY OF A NICKEL HYPERACCUMULATOR PLANT, BREYNIA CERNUA, IN THE ULTRAMAFIC TERRAINS OF ZAMBALES, PHILIPPINES

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A recent discovery of a nickel hyperaccumulator identified as *Breynia cernua* was made in the ultramafic regions in the Province of Zambales, Philippines. This is one of the first few species identified as a nickel hyperaccumulator since 1986, when a number of nickel accumulators were identified in Palawan. There was an initial interest on the plant as a nickel hyperaccumulator when a positive purple coloration was observed after using the dymethyglyoxine – impregnated filter analysis in the plant leaves and after a chemical analysis for nickel was made which gave values of about 3000 μg/g. Follow up field sampling and analyses confirmed *Breynia cernua* as a nickel hyperaccumulator. It was noted that nickel is mostly stored in the leaves with values ranging from 1,900 – 6,180 μg/g. Corresponding analyses were made on the laterites and serpentinites found in the area where the plant grows. Studies on the plant growth looked into the soil pH, phosphate, nitrate and organic matter contents, conductivity and the bioavailability fraction of nickel.

EFFECT OF AMF INOCULATION ON GROWTH AND CU UPTAKE AND TOXICITY OF *Desmodium cinereum* (KUNTH) D.C.

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The effect of arbuscular mycorrhizal fungi (AMF) on copper uptake and toxicity of *Desmodium cinereum*, a forage leguminous species, was studied. AMF inoculated and uninoculated pre-germinated seeds of *D. cinereum* were grown in sand-soil mixture treated with increasing Cu concentration (0, 400, 800, 1200, 1600ppm). Increasing Cu concentration gave a corresponding reduction on height, diameter, leaf area and biomass of the plants. Root growth was extremely inhibited at 1200 and 1600ppm Cu level. Nodule formations of the seedlings were also negatively affected. Mycorrhizal inoculation helped alleviate effects of Cu toxicity as indicated by greater growth of plants and greater phosphorus (P) uptake on different Cu levels. Inoculation also improved nodule formation which is positively correlated with plant growth. Increasing Cu concentration resulted to greater Cu accumulation of roots and stems. The highest Cu concentration on leaves was at the 1200ppm and 800ppm Cu level for uninoculated and inoculated respectively and after that Cu concentration starts to decline. Copper concentration was greatest on roots, followed by stem and least on the leaves. Mycorrhizal inoculation increased Cu uptake of roots, stem and leaves of the seedlings. Although Cu concentrations on roots for both inoculated and uninoculated were extremely high due to the addition of increasing Cu, concentrations on stem and leaves were still in normal range. The ability of AMF to improve Cu uptake and at the same time mitigate its toxic symptoms and promote growth of other beneficial microorganisms makes it an ideal tool for remediation of heavy metal contaminated sites.

PHYTOEXTRACTION OF LEAD-CONTAMINATED SOIL USING VETIVER GRASS (*Vetiveria zizanioides* L.), COGON GRASS (*Imperata cylindrica* L.) AND CARABAO GRASS (*Paspalum conjugatum* L.)

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The global problem concerning contamination of the environment as a consequence of human activities is increasing. Most of the environmental contaminants are chemical by-products and heavy metals such as lead (Pb). Lead contributes to a variety of health effects . An alternative way of reducing Pb concentration from the soil is through phytoremediation, an alternative method that uses plants to clean up contaminated area. This study was conducted: (1) to determine the survival rate and vegetative characteristics of three grass species such as vetiver-grass, cogon grass and carabao grass grown in soils with different Pb levels; and (2) to determine and compare the ability of three grass species as potential phytoremediators in terms of Pb accumulation by plants.

On the vegetative characteristics of the test plants, vetiver grass registered the highest whole plant dry matter (33.85 - 39.39 Mg ha-1). Vetiver grass also had the highest percent plant survival which meant it best tolerated the Pb contamination in soils. Vetiver grass registered the highest rate of Pb absorption (10.16 ± 2.81 mg kg^{-1}). This was followed by cogon grass (2.34 ± 0.52 mg kg^{-1}) and carabao grass with the mean Pb level of 0.49 ± 0.56 mg kg -1. Levels of Pb among the three grasses (shoots + roots) did not vary significantly with the amount of Pb added (75 and 150 mg kg^{-1}) to the soil.

Vetiver grass possesses many beneficial characteristics to take up Pb from contaminated soil. Vetiver grass can be used for phytoextraction on sites contaminated with high levels of heavy metals, particularly Pb.

REMOVAL OF CADMIUM AND OF COPPER FROM ACIDIC WATER BY CARABAO GRASS, PARAGRASS AND GOOSE GRASS

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Axonopus compressus (carabao grass), *Brachiaria mutica* (paragrass) and *Eleusine indica* (goose grass) found in Iligan City, Philippines, were investigated for phytoremediation of Cadmium and Copper acidic water. Grasses were washed and were placed in aerated water at the root level. After one day, the soaked soil were easily removed from the roots. Clean grasses were cultured in a semi-hydroponic media without root media and without fertilizer for one week. Grasses were treated either with Copper or Cadmium at 10 ppm concentration level in formulated acidic water. pH of the wastewater was maintained at 2.38 – 4.01 by continuous addition of stronger acid to the wastewater during treatment. Grasses were harvested after one-, two- and three- day exposure. These were immediately washed and dried. Cadmium and Copper were determined by Atomic Absorption Spectrophotometer in MSU –Naawan.

Axonopus compressus was found to have the highest root uptake of copper and to translocate copper to the stem-leaf parts while *Eleusine indica* had the highest root uptake of cadmium after two day exposure. These suggest if phytoremediation of copper employs harvesting of leaves, carabao grass could be used because it has a significant copper uptake in its stem-leaf. However, if translocation of copper to the leaves is a disadvantage, goose grass or paragrass could be used since they have significant low copper uptake in their stem-leaf. Furthermore, *B. mutica* (paragrass) or *E. indica* (Goose g.) could be used and be harvested after the second day for high removal of copper and of cadmium from acidic water.

ABSTRACTS OF POSTER PAPER PRESENTATIONS

NATURAL WASTEWATER TREATMENT FACILITIES USING FACULTATIVE STABILIZATION POND AND CONSTRUCTED WETLAND FOR LAGUNA DE BAY , PHILIPPINES

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Wastewater from the shoreland cities and municipalities of Laguna de Bay is directly discharged to the Bay. Wastewater contains contaminants altering the physical, chemical and biological aspect of the receiving body water or discharge area. Thus, affordable wastewater treatment facility is needed to lessen, if not remove, the contaminants from the wastewater. One of the municipalities in the shoreland was chosen as pilot area- the municipality of Paete.

In order to determine the type of wastewater treatment facility that will be designed and installed in the municipality of Paete, the socio-demographic,

economic and bio physical profile of Paete were properly investigated as well as the characteristics of the wastewater. The physico-chemical and microbiological parameters of the water from the nine irrigation canals and from the Paete river measured and analyzed were: turbidity, pH, TDS, DO, temperature, conductivity, salinity, TSS, PSD,TKN, TP, BOD, surfactant, oil & grease, total and fecal coliform. The results of the analysis confirmed the effluent standard for class C, except for oil & grease, and BOD in one site and the total and fecal coliform measured in all sites. The results confirmed the observed scenario in which floating human wastes go with wastewater. The presence of significant numbers of coliform is evidence that the water was contaminated by fecal material and any pathogen that leave the body through the feces can be present. The excessive amount of oil and grease is an indication of oil pollution which may interfere with the water treatment efficiency. It can interfere with the biological life in the surface of water and create unsightly floating matter and films. Statistical analyses showed significant mean differences of most of the parameters per sampling site and sampling season.

Result showed that flow rate of the wastewater was being altered by the deposition of solid waste in the irrigation canals and in the river.

This study revealed that the Natural Wastewater Treatment using Facultative Stabilization Pond and Free Water Surface type of constructed wetland is appropriate in the area. The existing aquatic plants will be utilized as phytoremediators in the constructed wetland. Hence, the design of the facilities revealed large area requirement. A pilot plant should be constructed first to come up with the established facility specifications as bases for expansion. Appropriation of funds for the pilot project did not materialize early; hence the study was focused only on the pre-construction phase. However, the recommended activities for the construction and operation phase from the original project design were included.

PHYTOREMEDIATION POTENTIAL OF SWAMP CABBAGE (*Ipomea aquatica*) ON THE WASTEWATER OF CORNICK PRODUCTION IN PAOAY, ILOCOS NORTE

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Cornick is derived from corn (*Zea mays*). It entails the use of huge quantity of water from the raw form up to its finished product. A day's production would require one cubic meter of water. When this wastewater is not properly treated and disposed in the environment, it will attract bacterial growth and cause pollution.

The absorption rate was taken every other day for the duration of the study. Treatments were as follows: (T1) pure water and swamp cabbage, (T2) 18.75% wastewater and swamp cabbage, (T3) 37.5% wastewater and swamp cabbage, (T4) 50.25% wastewater and swamp cabbage, (T5) 75% wastewater.

It was observed that the absorption rate of the plants decreased at higher concentrations of wastewater. The control of pure water and swamp cabbage had an absorption rate per day of 164.75 ml. while Treatment 2, Treatment 3, and Treatment 4 followed with a decreasing absorption rate. The decomposition of plants and increase in the suspended solids caused the water to become warmer and lessened its ability to hold oxygen. Lowest concentration of dissolved organic matter (DOM) was observed in Treatment 1 (control) and Treatment 2 respectively. The DOM increased as the concentrations of wastewater is increased. High amount of organic matter can be a source of food for microorganisms which will utilize the oxygen in the water. The pH of Treatment 1 to 3 became alkaline after the study. Treatment 4 and 5 decreased in pH due to the decomposition of plant parts. Salinity of T2 to T4 decreased from 2.33, 4, 5 ppt respectively to 1 ppt. Nitrate content in Treatments 2 to 4 decreased, however, Treatment 2 has the most significant decrease after the final sampling. It means that *Ipomea aquatica* can efficiently absorb and reduce nitrate content in wastewater.

BIOREMEDIATION AND ECONOMIC EFFICACY OF VFA BY MICROBIAL PRODUCTS IN PIG SLURRY

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A study was done to compare varying reduction rates of Volatile Fatty Acids (VFA) in pig slurry by different commercial microbial product concoctions. Results disclosed that two commercial microbial products demonstrated zero concentration of acetic, propionic, iso-butyric, butyric, valeric and iso-valeric acids. The above findings indicated a very effective bioremediation effects of some microbial products in reducing the obnoxious pollutants in pig slurry while some were not very effective resulting to very minimal reduction rate only. Cost Benefit Analysis on the use of the microbial product resulted to recovery of investment intervention. Considering that pig slurry can be a major source of pollutant, the treatment of pig slurry or lagoon in the Philippines should now be widely disseminated and the mass production of the microbial products should be pursued.

DEGRADATION OF SELECTED INSECTICIDE RESIDUES IN THE SOIL USING *Fusarium* sp.

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The potential of *Fusarium sp.* to degrade three commonly used insecticide residues in the soil was evaluated. The three insecticides used were carbaryl, chlorpyrifos and diethyl mercaptoccinate. These were applied in the soil and subsequently inoculated with *Fusarium sp.* The residue levels of the three insecticides in the soil were then monitored from inoculation onwards.

Different percentages of the insecticides (.001, .01, .05, .10%) were also supplemented to nutrient Agar, Potato Dextose Agar to test the growth of *Fusarium* sp. in test tubes.

Results showed that the degradation of the insecticides with *Fusarium* sp. was faster by 4 days as compared to the treatment without *Fusarium* sp.. Longer degradation was observed on carbaryl. The organism was able to grow in the different culture media with up to 0.1% of insecticide. The fungus was also isolated on the soil after degradation of the insecticides. The growth of the organism further shows that the organism was not only able to degrade the insecticides but also able to survive. The results show that *Fusarium* sp. has the potential to degrade insecticides.

MICROBIAL AND PESTICIDAL ANALYSIS OF SOIL AND WATER FROM PAOAY LAKE, PAOAY, ILOCOS NORTE

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The legendary Paoay Lake at Brgy. Sungadan, Paoay, Ilocos Norte is one of the tourist attractions of the province since it is located near the Malacañang of the North built by the Late President Ferdinand E. Marcos. However, the Lake has become a major concern because of the increasing stresses human beings have exerted onto it. The chemicals that are used for agricultural purposes are slowly contaminating the lake, since open fields surround it.

Hence, the study was conducted (1) to characterize the physico-chemical properties of soil and water samples;(2) to determine the pesticide residue in soil sediments and water; (3) to isolate and characterize bacteria from rice fields positive for pesticide residue; and (4) to determine the tolerance of isolated bacteria to varying concentration of pesticide.

Physico-chemical analysis revealed that all the four stations have a recorded temperature within the range of 30^0C to 35^0C; soil texture was clay or clay-loam soil; soil pH was alkaline. The highest percentage content of organic matter was obtained in station I while station II showed the highest potassium content.

Pesticide residue analysis showed that the soils from stations 1 and III were positive for carbamate residues and station I showed a positive result for organophosphorus residues.

Results showed that there were eight (8) bacterial isolates from the two sampling sites and these were all Gram positive (+) bacteria. These isolates can survive and tolerate the carbamate and organophosphorus pesticide as revealed by the confirmatory test.

A SYSTEMS BIOLOGY-BASED APPROACH TO PREDICTING BIOREMEDIATION OUTCOMES

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The increasing availability of the genome sequences of microorganisms involved in important bioremediation processes makes it feasible to consider developing genome-scale models that can aid in predicting the likely outcome of potential subsurface bioremediation approaches. In a pioneering paper, a multi-discplinary collaboration of scientists from US and Canada (Scheibe et al., 2009) has developed a model, coupling a genome-scale reconstruction of the metabolic network of *Geobacter sulfurreducens* (Mahadevan et al., 2006) with the reactive transport model HYDROGEOCHEM in order to describe *in situ* uranium bioremediation.

The coupled genome-scale and reactive transport model predicted acetate concentration and U(VI) reduction rates in a field trial that were comparable to the predictions of a calibrated conventional model but without the need for empirical calibration, other than specifying the initial biomass of *Geobacter*. Their results suggest that such a systems biology-based approach could lead to the development of models that can be predictive, without empirical calibration, for evaluating the probable response of subsurface microorganisms to possible bioremediation approaches prior to implementation.

The poster, which was prepared by members of the BIO 291 "Topics in Systems Biology Class" will discuss the Scheibe et al. results and consider possible research studies in the Philippine setting.

PHYTOREMEDIATION POTENTIAL OF OYSTER PLANT (*Rhoeo discolor*) TO LEAD NITRATE (Pb $(NO_3)_2$)

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Phytoremediation is becoming an attractive alternative for cleaning up soil systems contaminated with lead nitrate. Oyster plant was evaluated for its potential to remove lead in the soil. Three concentrations of lead nitrate, 1.2mg/l, 3mg/l and 5mg/l were prepared and watered on potted oyster plants. The amount of lead nitrate that remained in the soil was measured after 6 weeks. The growth and survival of the plants were also monitored. Histological analysis was also done on the leaves of the plant to determine its effect.

The highest amount of lead absorbed by the oyster plant was observed at 5mg/l. As the number of lead nitrate increased, the absorption also increased. Lead nitrate slowed down the growth of the plant as shown by the smaller plants exposed to the lead nitrate. Histological observation shows that the plants exposed at higher concentration of lead nitrate had no defined stomatal

cell. The stomatal opening were also smaller. Despite the effect of lead, there was 100% survival. This proves that oyster plant can clean up lead contamination in the soil.

LEAD NITRATE (Pb $(NO_3)_2$) ABSORPTION USING SWAMP CABBAGE (*Ipomea aquatica*) in *IN VITRO* CONDITION

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The absorption potential of swamp cabbage to lead nitrate was evaluated under laboratory condition. Four concentrations of lead nitrate, 0.25 mg/L, 0.50mg/L, 0.75 mg/l and 1mg/l, were prepared and placed in beakers and subsequently six inches long swamp cabbage were introduced into the beakers. The amount of lead absorbed was measured after two weeks. Survival rate and vegetative parameters of swamp cabbage were also taken.

Lead absorption of the plant was highest in treatment with highest concentration of lead. All the plants survived during the two weeks exposure time, although leaf yellowing was observed on the leaves of the exposed plants. The intensity of yellowing increased with concentration of lead nitrate. All the plants grew in all the treatments but were observed to be smaller than the control. Likewise, the number of roots of the plants in the exposed treatments decreased as the concentration increased. The results show that swamp cabbage is an absorber of lead, thus can be an input to bioremediation. However, being a vegetable poses a health risk.

PHYTOREMEDIATION POTENTIAL OF SANITARY LANDFILL ASSOCIATED PLANT SPECIES IN LEAD-CONTAMINATED SOIL

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Phytoremediation is a biological process in which living plants are used to remove, accumulate, degrade, contain and stabilize environmental contaminants. It is an effective and sustainable technique in the rehabilitation of soil and water that are heavily polluted with inorganic and organic pollutants such as sanitary landfills that had stopped operation. The success of this technique depends on the selection of the right plant for decontamination. The first part of the study identified the dominant plant species inhabiting the Sanitary Landfill of Laoag City, Ilocos Norte and determined the lead, copper and zinc content of the four dominant species in the area by Atomic Absorption Spectrophotometry (AAS). The second part evaluated the lead uptake potential of the two most dominant species grown in lead- contaminated soil under pot conditions. The landfill was dominated by pinto-peanut (*Arachis pintoi*), cogon grass (*Imperata cylindrica*), tomato (*Lycopersicum esculentum*) and kamote (*Ipomea batatas*) and which contained 1.968 ppm, 0.875 ppm, 0.0908 ppm and 0.0844 ppm of lead, respectively. When grown for two months in lead-contaminated soils under pot conditions, pinto peanut showed significantly greater accumulation capacity for lead in their shoot (11.26 ppm) and root (8.74 ppm) than cogon grass which accumulated 1.47 ppm of lead in their shoot and 0.15 ppm in their root. Nevertheless, their % survival were the same (100%). The 100% survival of pinto peanut and cogon grass in lead contaminated soils and their high capacity to accumulate lead in their shoots and roots make them suitable plants to rehabilitate sanitary land fills.

BIOSORPTION OF LEAD(II), COPPER (II) AND ZINC (II) BY *Eichornia crassipes* (MART.) Solms-Laub (WATER HYACINTH)

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Fresh water resources include lakes, rivers, reservoirs, wetlands and groundwater. They provide majority of our nation's water resources for drinking, agriculture, industry sanitation as well as food including marine animals. However, the continuous discharge of industrial, domestic and agricultural wastes in rivers and lakes cause deposits of pollutants in sediments. Such pollutants include heavy metals which endanger public health after being incorporated in the food chain.

Biosorption has been considered to be an alternative technique to take up toxic ion metals from water streams. The general objective of this study was to explore the feasibility of biosorption for the removal of lead, copper and zinc in an aqueous solution using water hyacinth.

The water hyacinth was harvested at the Pamatakan River in San Antonio, Zambales. One kilogram of the air- dried sample was pulverized and sieved. The biosorption experiment was conducted as a function of contact time, pH, temperature and initial heavy metal concentration, after which the filtered solution was analyzed for residual heavy metals using AAS.

The results showed that at 15 minutes contact time, the saturation point of biosorbent was reached for lead. The optimum pH for lead and copper was at 4 while for zinc was at 8. The optimum temperature for lead and copper was at 300C while for zinc at 400C. It also showed that lead and copper fit the Langmuir and Freundlich Isotherms quite well. It can be concluded that water hyacinth has a big potential in the cheaper treatment of wastewater.

ISOLATION, IDENTIFICATION AND ASSESSMENT OF PHENOL DEGRADING ACTIVITY OF BACTERIA FROM SEDIMENT SAMPLES

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Phenol and phenolic compounds constitute majority of the toxicants present in industrial effluents. Effluent discharge may contain phenol concentrations as high as 1,000 mg/L. In the Philippines, this is aggravated by the absence of an organized sewerage system and sewage treatment facilities in most areas. The use of indigenous microorganisms capable of degrading high-strength phenol concentrations may help in reducing phenol to allowable concentrations and in remediating contaminated environments. In this study, three phenol degrading bacteria were isolated from sediment samples in Pasig City, Philippines. The isolates showed very good to excellent API® results and high sequence homology (>99%) to *Pseudomonas aeruginosa*, *Comamonas testosteroni* and *Bacillus thuringiensis*. In addition, phenol catabolic genes were also detected. All of the isolates contained catechol 2,3-dioxygenase (C230) gene, bearing the expected size of 356 bp. However, only *B. thuringiensis* was detected with phenol monooxygenase (pheA) gene (947 bp), suggesting the need for additional primer pair targeting large multicomponent phenol hydroxylase (LmPH) gene. In terms of their phenol degrading activity, all of the isolates were able to completely degrade 100 mg/L to 1000 mg/L in ≤72 h and tolerate up to 1500 mg/L. Addition of high concentrations of select heavy metals (Cu, CrIV and Zn) as well as NaCl (3% and 5%) in the medium significantly retarded the isolates' growth, reduced their phenol degrading efficiency and increased their acclimation period.

MERCURY UPTAKE OF MICROALGAE IN KEMATU RIVER, T'BOLI, SOUTH COTABATO

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Mercury contamination from continuous flushing of mine silts into the Kematu River by small-scale miners in T'boli threatens human and environmental health as it flows through a major river in several agricultural towns in South Cotabato and neighboring areas. The Kematu River was chosen to be a potential source of mercury adapted microalgae for potential bioremediation. Microalgae were isolated from selected sites in the Kematu River. The ability of microalgae to remove mercury was studied through experiment at 100 mg/L concentration of initial mercury introduced in the medium with microalgal suspension. This study was also conducted to characterize and identify the isolated microalgae. Three isolates of microalgae from the Kematu River upon examination belonged to genera *Scenedesmus*, *Chlorella*, and *Oscillatoria*. The *Scenedesmus* sp. and *Chlorella* sp. microalgal isolates belong to Division Chlorophyta while *Oscillatoria* sp. belongs to Division Cyanobacteria. It was determined that *Chlorella* sp. had the highest maximum uptake capacity of mercury at 40%, followed by *Scenedesmus* sp. with a capacity of 30%. The *Oscillatoria* sp. had the lowest absorbance capacity of 10%. The results indicate that the isolated algae had mercury removal capacity and show potential bioremediation application on water contaminated with mercury.

IN VITRO AND *EX SITU* BIOREMEDIATION OF CONGO RED AND CRYSTAL VIOLET DYES BY LOCALLY ISOLATED MARINE FUNGI

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Synthetic dyes, e.g. Congo red and crystal violet, are used in textile and paper industries. If these dyes are not treated properly prior to its disposal, these can cause water pollution. Marine fungi can then be tapped for the bioremediation of these synthetic dyes. Fungi belonging to the genera *Acremonium*, *Alternaria*, *Coniothyrium*, *Phialophora*, *Phoma* and *Tolypocladium* were isolated from seawater and marine sediments (MF) and from living seagrasses (EMF). These were tested for their ability to decolorize synthetic dyes. Our results showed that majority (22) of the 26 fungal strains tested showed partial to full dye decolorization of 0.01% crystal violet (CV) using the tube overlay method. Decolorization also occurred best on Potato Dextrose Agar (PDAS) and least on Czapek Dox Agar (CDAS), all supplemented with 33g/L marine salts. Then, three marine fungal strains were further tested for the decolorization of different synthetic dyes, e.g. crystal violet and Congo red, in liquid media (PDBS) under agitated and stationary conditions. All strains (EMF14, MF6 & MF49) completely decolorized Congo red regardless of the culture condition and within 2 weeks of incubation. On the other hand, even after 4 weeks, EMF14 and MF49 exhibited only 87-91% decolorization of crystal violet. Finally, MF6 was tested for the *ex situ* bioremediation of Congo red using natural seawater with 0.1% and 0.5% Congo red dye. Following incubation for two weeks under stationary condition, spectrophotometric analysis showed color reduction and, thereby, confirming the dye decolorization potential of marine fungi under natural environment.

DETERMINATION OF THE OPTIMUM DEVELOPMENTAL STAGE OF THE *Moringa oleifera* LAM. SEED FOR WATER CLARIFICATION AND PURIFICATION

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Moringa oleifera Lam. (malunggay) seed extract has been found to be an effective coagulant for turbid water and possesses antimicrobial properties for water treatment. This study presents a comparison of the different

developmental stages of the *M. oleifera* seed as treatment for rainwater and Marikina river surface water. Crude extracts used to treat the samples were prepared from the different developmental stages of the seed: young, middle aged, green mature, and dry mature. Rainwater treatment did not present effective results in terms of decreasing the turbidity and microbial count of the water. For river water treatment, the dried mature seed extracts resulted to a decrease in turbidity, conductivity, and coliform presence by 99.05%, 4.31%, and more than 94.38%, respectively. T-test results presented a significant change in the pH, conductivity, turbidity, and microbial count showing that the treatment is much more effective in highly turbid water. An Analysis of Variance (ANOVA) showed that the different developmental stages resulted in significantly different results, with the dried mature stage showing greatest improvement in water quality parameters This study can help optimize the use of the malunggay seed, address the need for efficient water treatment, and possibly provide a source of livelihood for rural communities.

BIOREMEDIATION OF AGRO–INDUSTRIAL WASTES

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Wet poultry manure and coco peat wastes were composted and treated with microbial inoculants to reduce the waste volume, remove odor, and sanitize the solid residuals. Pilot composting studies were done in San Jose, Batangas. Poultry wastes came from the surrounding poultry farms in the area, while the coco peat were from coir fiber factories in Laguna. Microbial inoculants were prepared and consisted of nitrogen-fixing azotobacters and cellulolytic trichodermas. Different blending ratios of raw materials for effective composting were evaluated. Laboratory experiments established the techniques for enhanced degradation, optimum conservation of nutrients, and survival of inoculants in the processed product. The large-scale bioremediation method involved the use of payloader, large composting windrows or beds, and incubation time of 16 days in combination with

microbial inoculation. The process stabilized the N content of the resulting compost at 1.4 %, P_2O_5 at 6 %, and pH at 6. The inoculated solid residuals proved to be effective organic fertilizers. Field experiments in rice gave yield increases equivalent to that of chemical fertilizer at 90-60-60 at application rate of ten 50-kg bags per hectare.

TO BE OR NOT TO BE: BIOREMEDIATION AT THE FOREFRONT OF ENVIRONMENTAL BIOTECHNOLOGY

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Research activities on the use of biological systems for pollution mitigation have spanned more than three decades, touching on applications of various natural and modified microorganisms and plant species for the removal and detoxification of organic and inorganic pollutants. To date, few industries offer bioremediation services, which are heavily dominated by entities from the First World countries. At the same time, the apparent indifference in using bioremediation as an endorsed technology at the national level is observable. On the one hand, research scientists work very hard to develop or improve on existing bioremediation applications. On the other side, is the perceived reluctance by many policymakers and investors to support scale up research and development, and eventual translation to become an effective environmental technology.

Questions raised impinge on the following areas, among others - legitimate lack of basic knowledge in bioremediation on the part of policymakers and the general public, low priority of environmental protection as a national initiative for funding, effects on the other industries offering conventional anti-pollution technologies, apparent customization of methods due to specificity in types of pollution problems, as well as the spatial and temporal factors involved, and the unresolved questions on simple relocation of pollutants in the bioremediation cycle, or if indeed, there is a tail end of the process.

Unless these issues are resolved, or at the least, taken seriously and concretely by all stakeholders, progress in pushing bioremediation to the forefronts of environmental biotechnology will remain impeded.

HEAVY METAL REMOVAL CAPACITY OF DRIED BIOMASS OF *Eichhornia crassipes*

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Heavy metals pose harmful effects on the environment and human health. Biosorption is now being recognized for heavy metal removal because of its cost-effectiveness and removal efficiency. *Eichornia crassipes*, the biosorbent material that was used in the study, was identified to be an invasive species due to its high proliferation rate and posed problems in Lake Palacpacquen. Several studies have proven that live water hyacinth can be used for phytoremediation and recovery of heavy metals but only few studies have ventured on the use of dried water hyacinth biomass for biosorption of heavy metal. Hence in this study, the biosorption capacity of dried biomass of *E. crassipes* for the removal of different heavy metals such as Cu, Pb, Cd, and Hg were investigated. Sorption of copper, lead, cadmium, and mercury were affected by parameters such as initial metal concentration, contact time, and pH. Rapid adsorption occurs at the first 30 minutes of sorption and reached saturation at around 60 to 90 minutes. Results of the study revealed that the dried biomass of *E. crassipes* has the potential to clean up waste water or mine tailings because it can remove around 60-80%of metal in prepared aqueeous solution. FTIR Analysis of samples showed the different functional groups (hydroxyl and carboxyl) responsible for sorption. Further studies on the mechanism of adsorption and studies on the adsorption of a multi-metal system are recommended.

LEAD ABSORPTION CAPACITY OF TAPE GRASS (*Vallisneria gigantea* Graebner)

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Aquatic plants, such as the submerged aquatic vegetation that have roots and multi-celled structure, appear to take up metals like lead (one of the most damaging metals that affects human health through uptake of food (65%), water (20%) and air (15%)) than plants without roots. *Vallisneria gigantean* Graebner or tape grass or locally known as balaiba, is an aquatic weed common in shallow water, lakes, streams and still waters throughout the Philippines. The plant is almost stemless producing many stolons, with thin long ribbon-shaped leaves of varying lengths from few centimeters to 2 cm or more and about 1 cm wide. The length usually depends on the depth of the water. Their fast growth makes them great oxygenators and nutrient removers in aquaria (Vallias, 1999).

This study was conducted to evaluate the lead absorption capacity of tape grass specifically to determine concentration of lead absorbed by the plant and the histological qualitative differences in terms of cell wall, chloroplast number and cell size between the control and treatments used.

The treatments used in the study were 2.1 ppm, 2.8 ppm and 3.5 ppm lead acetate, each treatment in four replicates. Treatment concentrations was based from lead uptake of plants in 7% at a range of 30-50 ppm (Dharmananda, Lead Content of Soil). Lead concentration was measured by plotting the absorbance value obtained using spectronic 20 at 370 nm wavelength.

After four weeks of treatment, plants treated with 3.5 ppm lead acetate had the highest absorption (1.28 ppm) followed by 2.8 ppm (lead aborption at 1.07 ppm) and the least absorption at 2.1 ppm (lead absorption 0.85ppm). Physico-chemical parameters such as water, temperature, pH, dissolved oxygen and total dissolved solids in the treatments were also determined in the study.

Histological differences occurred: cell wall size, chloroplast number and cell size . In the leaves swollen cells were observed in the treated plants, cell wall thickens as the treatment increases except for the plants treated with 3.5 ppm lead acetate and the number of chloroplast decreased as treatment increased. In the roots, there is an observable swelling, especially at the tips. Cells in the elongation region were also swollen and elongated.

Qualitative analysis should be performed in the histological differences in terms of measurements of the cell wall, chloroplast number and cell size. Further, concentrations should be increased to test the maximum tolerable absorptive capacity of tape grass.

ASSESSMENT OF DIFFERENT LEVELS OF ZEOLITE TO IMPROVE POND BOTTOM SOIL AND WATER QUALITY FOR NILE TILAPIA CULTURE

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Zeolite are microporous alumino-silicate compounds usually used as adsorbents. With their natural ion exchange adsorption and hydration properties, these minerals have broad application for agricultural and aquacultural studies. Zeolite can reduce ammonium and hydrogen sulfide levels in fish ponds resulting in increased growth rate and population densities.

The study aimed to assess the different levels of zeolite, 10%, 20% and 30% for the improvement of used pond bottom soil, water quality as well as to monitor its effect on the cultured fish.

Used pond bottom soil from a commercial fish pond was brought to the laboratory and treated with different levels of zeolite. Used water from a fish tank was added to each aquaria and stocked with Nile tilapia fingerlings. Soil and water samples were brought to the laboratory for analysis. The effect of different levels of zeolite on the ABW, percent survival, population density and FCR of the fish were observed.

Results of this study showed that zeolite was able to improve the pond bottom soil by increasing the pH and decreasing the concentration of sulfates, ferrous and percent organic matter. The effect of zeolite upon treatment on water quality decreased the electrical conductivity and pH slightly. Zeolite also increased the chemical oxygen demand (COD) and total soluble solids (TSS). Zeolite was also able to increase the survival, population density and biomass of the fish *Tilapia nilotica*. Results showed that the best concentration of zeolite that is recommended for aquaculture is 20%.

BIOSORPTION OF COPPER BY A BACTERIAL ISOLATE FROM MOGPOG, MARINDUQUE USING TWO AGRICULTURAL BY-PRODUCTS AS BIOFILM CARRIERS

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Heavy metal (HM) pollution is a major environmental concern in the Philippines. Biofilm-mediated bioremediation presents a proficient and safer alternative method of HM removal in contaminated wastewater. Microorganisms that secrete polymers and form biofilms maybe well suited for cleaning up heavy metals contaminated sites because of their high microbial biomass and ability to immobilize metals by biosorption, bioaccumulation and biomineralization. In this study, six bacterial isolates were obtained from heavy metal contaminated sites in Mogpog, Marinduque. The isolated bacteria were screened for their ability to form biofilm and their tolerance levels to selected heavy metals were determined. The most effective bacterial isolate in terms of biofilm formation and tolerance to heavy metals was characterized and properly identified. The identified isolate was immobilized as biofilm onto rice hull and coco coir carriers. The effectiveness of the immobilized bacterial biofilm in removing copper was assessed in the laboratory using artificially prepared copper contaminated water. Results showed that the six isolates were resistant to lead, cadmium, copper and zinc. Isolates designated as 3U29, D15 and D29 were able to grow at 510 ppm Pb, 4.8ppm Cd, 216 ppm Cu and 840 ppm Zn while 3P9, 3P28 and 3U16 survived at 680 ppm Pb, 6.4 ppm Cd, 288 ppm Cu and 1120 ppm Zn. Microtiter Plate Biofilm Assay and scanning electron microscopy revealed that only isolate 3U29 was capable of forming biofilm and therefore 3U29 was used in the biofiltration experiment. The biofilter set-ups utilized a plastic column with a diameter of 29 mm and a height of 45 mm. The column with coconut coir as biofilm carrier showed 0.3% copper reduction. The biofilm forming isolate was identified to be *Staphylococcus lentus*. The preliminary results in this study showed the potential of *S. lentus* biofilm immobilized onto coco coir carrier in reducing copper in contaminated water.

BIOACCUMULATION OF CHROMIUM BY *Chlorella vulgaris* AND *Scenedesmus quadricauda*

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Industrial activities have led to widespread chromium (Cr) contamination in the environment. Its hexavalent form is toxic, mutagenic and carcinogenic. Consequently, the presence of Cr in the environment poses a serious threat to both humans and animals. This study examined the effects of varying levels of Cr and (0,1 and 3 ppm) after 12 days of incubation period on two local microalgae, *Chlorella vulgaris* Beijerinck and *Scenedesmus quadricauda* (Turp.) de Breb, a green and blue green algae, respectively. The response of the microalgae to Cr were assessed based on cell morphology, growth (measured as algal density) and bioaccumulation capacity.

Increasing Cr concentrations reduced the growth of both microalgae. However, *C. vulgaris* showed a higher optical density (OD) of 0.56 and 0.33 than *S. quadricauda*, 0.18 and 0.13, at 1 ppm and 3 ppm Cr, respectively. At

3 ppm Cr, the cells of *S. quadricauda* and *C. vulgaris* showed abnormalities and deformities. The cells also appeared pale, an indication of chlorophyll loss. *C. vulgaris* removed 61% and 63% of Cr from the treatment solution; while *S. quadricauda* removed 54.3% and 61.4% at 1 and 3 ppm, respectively. These results showed that both microalgae showed the capacity to remove Cr from the treatment solution thru bioaccumulation.

MICROBIAL REMEDIATION ON THE FISHPOND WATER IN BARANGAY LIPUTAN, MEYCAUAYAN, BULACAN

Edgar E. Maranan
President, 5455 E. Solutions

A pilot test for a microbial remediation technology in an experimental fish pond, 153 sq.m with approximately over 1 m in depth area located in Brgy. Liputan, Meycauayan, in the province of Bulacan was conducted from January – March 2009. Water and sediment samples were taken before and after the bioremediation technology was introduced in the experimental site and analyzed by DENR-accredited laboratories. A physical transformation from dark to clear river water was observed after the bioremediation of the fishpond waters. The unfavorable stench of the river water in the pilot area was also effectively removed after five (5) days of bioremediation. In addition, the dissolved oxygen (DO) which was at only 0.1 mg/L prior the treatment was also effectively raised to 3.39 mg/L level within the 15-day period. The results after only 15 days of bioremediation showed that the process successfully reduced the amount of all heavy metals present in the MMO river waters in the pilot area as well as its sediments. This shows that the carefully selected microbial isolates utilized proved to be very effective biological agents for the reduction of concentration of heavy metals in the river system. All heavy metal readings after 15 days of treatment are within the standard set by EMB for soil and for water except for manganese and copper. A prolonged bioremediation activity of an additional 15 to 30 days is believed to reduce further the heavy metal content in the river water and sediments.

ASSESSMENT OF MYCORRHIZAL DIVERSITY AND THEIR GROWTH EFFECTS ON *Acacia mangium*, *Paraserianthes falcataria* AND *Xanthostemon verdugonianus* IN MARGINAL AND MINE WASTE SOILS OF MANILA MINING CORPORATION, PLACER, SURIGAO DEL NORTE, PHILIPPINES

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Phytoremediation, an emerging technology uses plants to clean-up pollutants from the environment. This study was conducted to assess the mycorrhizal diversity and its growth effects on *Acacia mangium*, *Paraserianthes falcataria*, and *Xanthostemon verdugonianus* (mangkono) in marginal and mine waste soil of Manila Mining Corporation (MMC), Placer, Surigao del Norte, Philippines. Reconnaisance survey and collection of soil, root and plant samples were conducted at MMC. Mycorrhizal fungi were isolated and screened for plant growth promoting ability. Height and diameter were measured bi-monthly, post growth data and, P and Cu plant analyses were obtained after three months.

Generally, plants grew better in marginal soil than in mine soil and mycorrhiza inoculated plants outperformed the uninoculated counterpart. The native MMC inoculum was the best for mangium and mangkono; however inoculation did not work on *Falcata* seedlings.

Mycorrhizal plants contained higher (0.51%) P than the uninoculated (0.22%) counterpart. The highest Cu concentration was observed in mycorrhizal *mangium* (72.50 µg/g) and the least was in uninoculated *Falcata* (8.00 µg/g). Mycorrhiza- infected roots were higher (6-14%) in *mangium* grown in marginal soil than in mine soil (3-9%).

Acacia mangium is one candidate for rehabilitation of Manila Mining Corporation, Placer, Surigao del Norte followed by mangkono. It is highly recommended that the plant growth- promoting potential and heavy metal accumulation of MMC inoculum be studied under field conditions as well as in other copper-rich soils.

BIOAVAILABILITY AND ACCUMULATION OF HEAVY METALS IN SOIL AND EDIBLE PLANTS FROM AREAS NEAR MANILA MINING PLACER, SURIGAO DEL NORTE

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The presence of mining companies have a big impact on the environment and also on the health of the residents living nearby. This led the researchers to conduct an experiment about the bioavailability and accumulation of heavy metals in soil and edible plants from areas near Manila Mining Corporation, Surigao del Norte where small scale miners have also been operating for several years now. The six sampling stations near MMC were chosen as these areas were near water tributaries and effluent discharge areas of the company.

The NPK test results revealed that the 6 soil samples were not significantly good for the plants to grow because the nutrients did not meet the sufficiency standard which is MMS (Medium N, Medium P, and Sufficient P). The soil samples taken from the six different sampling stations surrounding MMC accumulated small amounts of heavy metals, and silicon had the highest concentration (48.08% in Bayatacan). The edible plants, on the other hand, accumulated heavy metals in which 16 were detected in most of the samples while 15 were either detected at low concentrations or not detected at all under LOD of the XRF. Though some of them (Fe, Cu, Zn, Mn, K, Ca) under tolerable uptake level help the body's regulatory mechanisms, others are hazardous such as S, Mo, Zr and others. Calcium (18832 ppm), potassium (126021 ppm) and sulfur (52696.21 ppm) were detected at very high concentrations in all the edible plants, while zinc, iron and manganese are in moderately high concentrations. Furthermore, mercury was not detected in all the samples except in rice from Bayatacan where small scale gold processing plants were concentrated. Heavy metal translocation from soil to plants was evidenced by the fact that most of the metals were detected in plants but not detected in the soil.

From these results, the researchers have formulated an action plan to disseminate the information to Placer LGU, DENR-EMB and the MMC administration so that programs can be laid out for the benefit of the people in these areas.

PROPOSED BIOREMEDIATION AGENDA[1]

The National Bioremediation Agenda is an offshoot of the First National Bioremediation Conference held in Manila on October 26-27, 2010. The conference was a gathering of about 200 participants primarily from government, industry, and academe who shared their research results, experiences and concerns in the application of biological processes (both microbial and plant), for providing waste management solutions to a wide variety of problem wastes. The sharing of experiences in the conference led to the consensus, that with proper coordination of key players from government, industry and academe, bioremediation can offer cost- effective solutions to environmental problems in the Philippines. In order to realize the maximum potential of bioremediation applications in the country, the following are needed to be done:

(1) strengthen and promote bioremediation research and development
(2) provide support for technology transfer, utilization, and certification programs for developed bioremediation products/processes; and,
(3) grant information/communication infrastructure to provide information-based-decision tools for environmental policy formulation, as well as for public environmental education.

An action plan embodied in the National Bioremediation Agenda was drafted during the First National Bioremediation Conference. It is envisioned to be implemented in phases, initially starting with a "start-up" networking and information-sharing program, through the establishment of a National Network for Bioremediation. The initial phase will gradually lead to organizational activities to identify key-players and establishment of institutional mechanisms to address support for (1) bioremediation research, (2) technology transfer/ utilization/ certification, and (3) information-based environmental policy formulation.

The National Bioremediation Agenda is organized as follows:
(1) <u>Establishment of Institutional Mechanisms to Promote Bioremediation-based Solutions for Environment Applications</u>. Initially under the

[1] As proposed during the conference

DOST-NAST umbrella, an organizational analysis will be made in order to identify the key players involved in bioremediation research, application, technology transfer and policy-formulation. From the output of the organizational analysis, a core steering committee for the National Network for Bioremediation will be established. The Network will facilitate information sharing on issues related to bioremediation research, policy and technical solutions. The networking and information sharing-function is managed by the core steering committee. This will eventually lead to organizational activities and institutional mechanisms for the creation of a body that can contribute/harmonize national environmental policies which promote sustainable applications of bioremediation.

(2) Support Research and Development in Bioremediation. The core-steering committee, through its network with appropriate national agencies, and the industry will coordinate the tapping of financial support for promising or innovative bioremediation research, evaluation studies of environmental health impacts, or field trials of mature-technologies.

(3) Promote Tested Bioremediation Technologies and Strategies for the Mitigation of Pollutants. The core steering committee (and eventually, the established institutional body) will keep track of bioremediation technologies which have been proven successful in bench scale and field testing trials, and promote their application.

(4) Development of Certification System for Approving/Developing Standards on Bioremediation. In order to ensure sustainable and safe application of bioremediation technologies, there is a need to put in place certification programs for developed bioremediation products and processes.

SYNTHESIS AND CLOSING REMARKS

Asuncion K. Raymundo, PhD
Conference Convenor, Professor and Dean College of Arts and Sciences, UPLB; Academician, National Academy of Science and Technology

We are delighted that during this First National Bioremediation Conference we have gathered diverse and interested stakeholders, who generously shared their experiences and challenges they have encountered in the field of bioremediation.

There are those from the academe who have long been into innovative research in harnessing biodiversity in searching for solutions in environmental rehabilitation and wastewater treatment.

Likewise, we are fortunate that people from the industry came to express their concern over the environment and shared their experiences on the application of bioremediation technologies. In like manner, people in the public sector generously provided insights on efforts to integrate bioremediation technologies with policies all geared towards maintaining a safer environment for all constituents.

We are particularly elated that all age groups were represented in the conference. We heard the voices of "experience" and the impressive as well as reassuring presentations from our young people from the academe and industry (Mr. Michael Angelo Nicdao from Pampanga Agricultural College, and Ms. Michelle Mariel Lazaro are fine examples of youth for a better future environment for the Philippines).

The Conference provided an opportunity for academe, industry, government and other sectors to interact closely and to learn from other experiences. Overview of cases where hazardous waste have harmed the environment and how practical bioremediation/phytoremediation technologies have been applied were heard. Updates on interesting tools for extract organisms from both plants and microorganisms with new or improved bioremediation techniques as well as practical bioremediation technologies developed abroad and which could be adapted to Philippine conditions were unveiled. Presentations on how the government is coping with the management of hazardous wastes and how bioremediation might contribute were encouraging developments

The inclusion of sociological and health/toxicological dimensions in some of the presentations put forward the idea that in bioremediation the stakeholders' positions are vital consideration in solving environmental problems.

From the paper presentations, these are the technologies that can already be adopted, or adapted perhaps with some modification depending on the situation:

(1) The experience of Dr. Doronila can be consolidated and adapted to Philippine conditions

(2) Mine Waste Management – the practices of Philex Mining can be shared with other companies that are using underground mining techniques

(3) Bioremediation of abandoned mines – the results from our group efforts can be expanded – Our strategy of community participation has to be implemented to determine if it is workable (Need funding !)

(4) Bioremediation of Tannery Waste – the technology practiced by Chelsi Leather Systems, Incorporated has been proven successful.

(5) Bioremediation to clear up aquatic systems – the experience of Dr. Joshi and Prof. Marlo Mendoza of the Myecauayan-Marilao Obando River System can be considered.

The proposed technology of Edgar Maranan to clear up fishpond water should be confirmed.

For small water systems like a creek, the technology practiced by Dr. Macrina Zafaralla of UPLB has to be considered and adapted.

(6) Potential technologies that need to be subjected to additonal research are:

(a) Phytoremediation using marine heavy methyperaccumulators with subsequent phytomining

(b) For microbial remediation

- H2S precipitation
- biofilm formers
- lipase degraders
- bacterial oil degraders
- algal bioremediators
- phenol degraders

(7) Areas that cut cross disciplines are:

Health

Human perspective

Systems biology – possibly to analyze the interaction of the various components of the ecosystem and their effecs on pollution and its management.

With interactions such as those provided by the conference, an opportunity for networking and establishment of collaborations has emerged. We have realized that our "complementarity of strengths" can be a useful force in providing bioremediation solutions to real and pressing environmental problems in our country. We hope that this 'first' conference has provided the initial step toward this end.

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