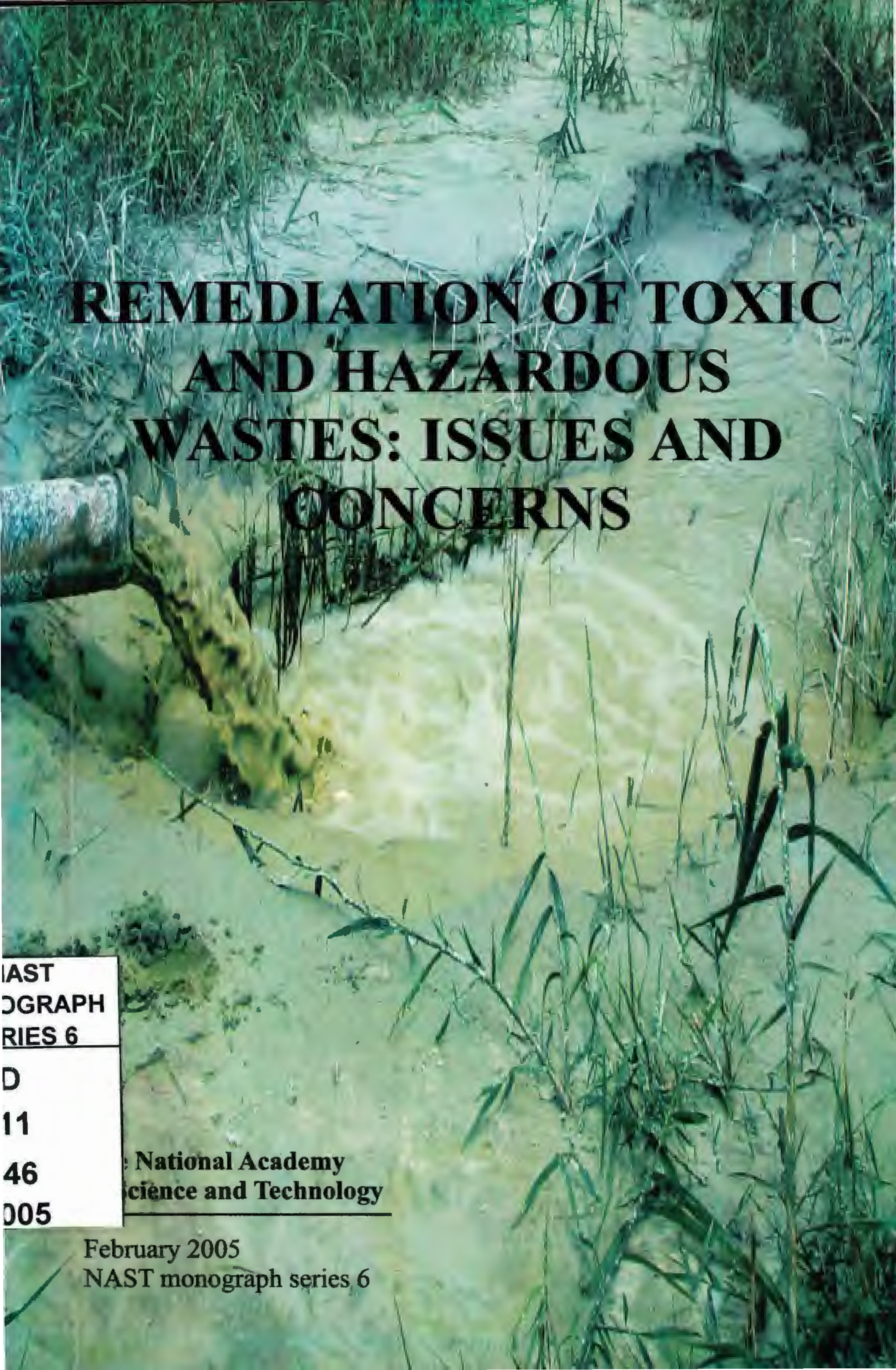


REMEDIATION OF TOXIC AND HAZARDOUS WASTES: ISSUES AND CONCERNS

National Academy
cience and Technology

February 2005
NAST monograph series 6

NAST Monograph No.6

ISSN 1655-4299

Editor: Academician Asuncion K. Raymundo
Editorial Staff: Edwin Camaya

Published by:
National Academy of Science and Technology (Philippines).
2nd/F Philippine Science Heritage Center
DOST Complex, Taguig, Metro Manila 1631
Philippines
Email: nast@dost.gov.ph, nast@mozcom.com
http://www.nast.dost.gov.ph

Cover photo: One of the mine tailings dump sites in the Philippines. (Courtesy of Dr. Nina Cadiz)

REMEDIATION OF TOXIC AND HAZARDOUS WASTES: ISSUES AND CONCERNS

THE NATIONAL ACADEMY OF SCIENCE AND TECHNOLOGY (PHILIPPINES)

FOREWORD

Progress usually exacts a steep price, whether in terms of social dislocation, the weakening or collapse of old institutions, the alienation of the individual, or the degradation of the environment. So identified with progress are these adverse effects that their appearance is taken as a sign of its presence, rather than as an unintended consequence. This is especially true of environmental degradation.

Several environmental nightmares, hot spots where the effects are particularly acute, have been reported in the past few years, with entire groups of people exhibiting symptoms of poisoning or grave illness. So serious are the consequences of these environmental disasters that the problem has acquired national or even international dimensions.

It was these persistent reports – in the former military bases and the mining areas of Marinduque and Compostela Valley, just to name a few – that caught the attention of the National Academy of Science and Technology (NAST). Here was an instance where in the NAST and related agencies in cooperation with government, the private sector, non-governmental organizations (NGOs) and the affected populace can pool their technical and scientific expertise to come up with a research oriented strategy for the solution/management of the problem,. For while technology might bring challenges, it also holds the key to the solution of most of them.

In this context, NAST created a Task Force on Toxic and Hazardous Waste spearheaded by Academician Asuncion K. Raymundo with Academicians Emil Q. Javier, Jose Q. Juliano, Apolinario T. Nazarea and Ruben L. Villareal. This group then organized a Seminar – Workshop on March 6, 2003 to discuss important matters. It was co-sponsored by Zuellig-Pharma. It is an auspicious beginning, with authorities from many fields, and no less than the Secretary of Environment and Natural Resources, in attendance. While we are aware that the task will be far from easy, the goodwill and linkages forged during the seminar-workshop give us cause for hope. With support from all concerned sectors, we know that a solution will be much closer than before.

This monograph is a compilation of papers presented during the workshop and feedback from the participants.

Acd. PERLA D. OCAMPO-SANTOS
President
National Academy of Science and Technology

TABLE OF CONTENTS

FOREWORD i

WELCOME ADDRESS
PERLA D. SANTOS-OCAMPO, President, National Academy of Science and Technology 1

MESSAGE
SECRETARY ELISEA GOZUN, Department of Environment and Natural Resources.. 3

MESSAGE
KENNETH HARTIGAN-GO, Executive Director, Zuellig Foundation.. 5

MESSAGE
ASUNCION K. RAYMUNDO, Academician and Workshop Coordinator 7

WORKSHOP PAPERS
ENVIRONMENTAL ASSESSMENT OF AREAS AFFECTED BY HAZARDOUS WASTES
Anna Leah U. Texon 11

MEDICAL AND HEALTH IMPLICATIONS OF TOXIC AND HAZARDOUS WASTE ON RESIDENTS IN THE AFFECTED AREAS
Irma Makalinao 28

CHEMICAL REMEDIATION OF TOXIC AND HAZARDOUS WASTES
Leni L. Quirit, Ma. Pythias B. Espino, and James B. Villanueva 33

BIOREMEDIATION OF TOXIC AND HAZARDOUS WASTES BY DENITRIFYING BACTERIA
Wilfredo L.Barraquio.. 44

REMEDIATION OF TOXIC AND HAZARDOUS WASTES: PLANTS AS BIOLOGICAL AGENTS TO MITIGATE HEAVY METAL POLLUTION
Nina M. Cadiz and Eduardo B. Principe..........................60

REPORTS OF THE DIFFERENT GROUPS DURING THE WORKSHOP PROGRAM

Group 1: Phytoremediation 81

Group 2: Microbial Bioremediation 83

Group 3: Health and Society 86

SYNTHESIS AND CLOSING REMARKS, Emil Q. Javier, Vice President, National Academy of Science and Technology..87

ACKNOWLEDGMENT 91

WELCOME REMARKS

ACD. PERLA D. SANTOS OCAMPO
President
National Academy of Science and Technology

The National Academy of Science and Technology (NAST) Philippines takes great pride in co-sponsoring this Seminar/Workshop on Bioremediation of Toxic and Hazardous Wastes with the Zuellig Foundation.

As our country moves towards economic development and industrialization, our environment is rapidly beginning to feel the pressure. Environmental degradation, pollution, and contaminated groundwater, soils, and bodies of water, are only some of the critical issues we have to address in order to attain sustainable development. One of the most urgent problems we are now facing is the presence of toxic and hazardous wastes in our midst. Republic Act 6969 of 1990, otherwise known as the Toxic Substances and Hazardous and Nuclear Wastes Control Act, characterized hazardous wastes based on their (a) toxicity - or poisonous (acute), carcinogenic or mutagenic effect on humans and other organisms; (b) ignitability - can create fire under certain conditions, e.g. friction sensitive substances like solvents; (c) corrosivity - acidic or basic, capable of corroding metals by chemical action which can cause severe damage when in contact with living tissue; and (d) reactivity - unstable under normal conditions and readily undergoes violent changes without detonating; reacts violently with water and can create spontaneous explosive mixture like toxic gases, vapors and fumes, all of which are capable of detonating.

According to data from the Environment Management Bureau, during the period from 1996 –1998 alone, about 34, 221' 920.26 MT (metric tons) of hazardous wastes were generated by the different industries here in the Philippines. It was only in 1999 when Philippine authorities discovered that Japan dumps its medical wastes here. Moreover, until recently, we are just realizing the legacy of toxic and hazardous wastes that the US bases have left behind. One very alarming occurrence is the high incidence of children born with abnormalities and impaired intelligence in the community near the former bases. This may be primarily due to the contamination of the groundwater with high levels of PCBs, HCBs and dieldrin, among others.

In more advanced countries, toxic waste clean-up tops the government's priority projects and thus gets a huge chunk of the annual budget. In the US, environmental clean-up could cost as much as US$1 trillion. Efforts to remediate environmental contamination under the Superfund Legislation -the Comprehensive Environmental Response, Compensation and Liability Act are underway. While bioremediation has been found to hold great promise for dealing with intractable environmental problems, there is still a great need for scientific research to increase its efficiency and applicability. Basic Research is being carried out by groups of scientists in various parts of the world with USGS (US Geological Society) scientists leading the way. Unique interdisciplinary expertise is needed such as microbiology, hydrogeology, and geochemistrty. The use of bioremediation in cleaning up existing environmental contamination is a viable alternative for a developing country like us. It is cheaper, sustainable and helps in reducing environmental stress.

Recognizing these, the National Academy of Science and Technology, during the 23rd Annual Scientific Meeting held last July 2001 formulated a resolution entitled "Recommending a Solution to the Problem of the Toxic and Hazardous Wastes (THW) Disposal". The Academy then organized the NAST Toxic Waste and Hazardous (THW) Disposal Committee with Acd. Asuncion K. Raymundo as Chair, and Acd. Emil Q. Javier, Acd. Jose O. Juliano, Acd. Apolinario D. Nazarea and Acd. Ruben L. Villareal, as members. The committee was assigned to look into this very timely concern. This seminar workshop is one of the major outputs of the Task Force. Great care was given to the selection of participants. With the presence of our brilliant line-up of speakers, we are confident that we can come up with relevant and useful recommendations and actionable strategies that would be effective in guiding our legislators and line function agencies concerned. Through our concerted efforts, we hope that the present and future generations of Filipinos can still enjoy a clean and healthy environment.

Thank you and mabuhay po tayong lahat!

M E S S A G E

Hon. Secretary Elisea (Bebet) Gozun
Department of Environment and Natural Resources

ISANG MAKAKALIKASANG UMAGA PO SA INYONG LAHAT.

I am happy to be invited before this very prestigious and honored group of scientists and academicians.

It is good that a wide range of our populace, notably the scientific community such as your organization, recognizes that environmental management is not a function of the government alone. Our department has been mandated to protect the environment, but we all know that this cannot be done by us alone. In the past many years, programs on environmental management, [waste minimization, waste prevention, technology development] were left to the government. It is heartwarming to know that the scientific community is sponsoring this seminar-workshop focused on toxic and hazardous wastes for the protection of the environment and human health. DENR is strengthening its linkages with the scientific and academic community.

The papers to be presented today will report on the status of hazardous waste generation in the country, as well as the steps being done by the government to address the problem. Hopefully, with these presentations, the scientific community will be able to identify in what specific ways it can assist the government and the industry in this area. In developed countries, we all know that the academe plays an important role in the conduct of different researches on hazardous wastes and other toxic substances and other areas of DENR management. For example, in Finland, researches in forestry are done by the schools and funded by the private sector, which stands to benefit from the output. One of our immediate problems is the lack of integrated facilities to handle tons of hazardous wastes that are reported to be generated. The scientific community can look into the practices/processes that are being implemented to treat, reduce or recycle these hazardous wastes. Are these treatment schemes sufficient in the handling of hazardous wastes such as lead?

Different technologies for the treatment of hazardous wastes are emerging. In today's presentation, the state of the art of bioremediation and phytoremediation will be discussed. It is indeed high time for us to assess these technologies, and if viable, to promote the same. I had been told about an article wherein a group of microorganisms was used in the treatment of PCB-contaminated sludge. We all know that we still lack technologies that can treat PCBs and other Persistent Organic Pollutants (POPs). Thus, we put our hopes on the implementation of the UNDP-UNIDO Project entitled Demonstration Viability and Removal of Barriers that Impede Adoption and Effective Implementation of Available Non-Combustion Technologies for POPs. While this project had been conceptualized two years ago, it is only recently that we have achieved a degree of progress, with the identification of PCB stockpiles in the country as well as potential operating entities for the project. Hopefully, POPs, such as organic chlorines, will also be handled by these facilities.

The DENR is also implementing a GEF-UNDP Project entitled "Philippine POPS Enabling Project." The project has three components that deal with PCBs: pesticides, dioxins and furans. There are sub-activities within this project where we can collaborate such as the conduct of a full inventory of PCB and PCB wastes in the country. This project is funded by the GEF to assist us in the implementation of the Stockholm Convention on POPs.

We hope that by the end of your noteworthy seminar-workshop, we will be able to concretize how the government and the scientific community can collaborate, for a safer environment for us and for generations to come.

MESSAGE

KENNETH Y. HARTIGAN-GO, M.D., FPCP, FPSECP
Executive Director, Zuellig Foundation

Firstly, I would like to extend to the organizers – Hon. Secretary Gozun, Academician Emil Javier, Academician Perla Santos-Ocampo, my Chancellor, Academician Asuncion Raymundo, and Academician Jose Juliano, my sincere gratitude for inviting me to deliver the welcome message in this seminar-workshop.

The rapid expansion of industrialization in the Philippines has led to an increasing amount of environmental toxic and hazardous wastes. This issue has become an urgent global concern that must be addressed by various stakeholders. I am glad that this is one opportunity for health and environmental experts and policymakers to convene together to identify the best solutions to address the problem.

The health threat of toxic and hazardous wastes (THWs) can be seen in two (2) ways: the accumulation of these substances in our environment and the unsafe disposal of the toxic components in the waste.

We are aware or told that the accumulation of wastes in some areas in our country such in the former US military bases, Boac River in Marinduque, and a dumpsite in Sapang Palay; Bulacan, leads to a high incidence of premature births, congenital deformities and miscarriages , as well as respiratory, cardio-pulmonary, cancer and endocrine problems. The children are the most susceptible to these diseases[1].

On the other hand, we are told likewise that conventional methods of waste disposal which include combustion, incineration and landfills have been associated with significant public health and environmental threats[2]. Dioxin is one of the dangerous pollutants released by incinerators. Significant exposure to this chemical would lead to endometriosis, thyroid function abnormalities, congenital deformities, child growth retardation, and other reproductive and oncologic problems. The International Agency for Research on Cancer has classified dioxin as a known human carcinogen.

So far, the key national agencies have addressed these health and environmental concerns through the enactment of Republic Act 6969 known as the Toxic Substances and Hazardous and Nuclear Waste Control Act of 1990 and the Philippine Clean Air Act of 1999. Republic Act 6969 covers the regulation and control of toxic chemicals, hazardous wastes and nuclear wastes, while the Clean Air Act explores, among others, alternative environment-friendly methods of addressing waste disposal management. These methods include non-burn technologies and promotion of waste reduction, re-use and recycling.

While there admittedly are other policy gaps and issues that need to be addressed, this seminar-workshop will also deal with establishing concrete remediation measures, whether chemical, bio- or phytoremediation, or a combination of these measures, to solve the health and environmental problem related to THWs.

In order to identify the best remediation measures, we have to take into account the following indicators for assessment: cost-effectiveness and risk benefits (if there are still any). Questions[3] that can be raised for assessment are as follows: 1)Is the method versatile (can the method address more than one pollutant)? 2) Is it energy-efficient? 3) Is it environment-friendly?

Once the remediation measures have been properly selected, it would also be important to develop the appropriate guidelines to implement these measures, determine the type of training and technology transfer needed to disseminate these methods, from the experts down to the local government units and other end-users concerned. Then, there must be political will to carry these out.

As a parting note: let's take good care of our planet Earth, our one and only sound ecological system in the universe. It is impossible for scientists to look for other earth-like planets to live in for the next generation if we will be the precursors to their destruction just the same.

[1]www.doh.gov.ph/bihc_publ/toxic_waste.html, Jan-Feb. 2002
[2]Incineration and other waste disposal technologies, WWF, Nov. 2001
[3]www.yestech.com/tech/biorem1.htm

REMARKS

ASUNCION K. RAYMUNDO
Academician, National Academy of Science and Technology and Workshop Coordinator

As our NAST President Dr. Santos-Ocampo has stated, the NAST Toxic and Hazardous Waste (THW) Disposal Committee decided to organize this event because of persistent, disturbing reports on the adverse effects of toxic waste in various hot spots around the country. Based on the accounts, this is a worsening problem complicating health, environment, economy and future prospects of the areas involved. We decided to tackle it not only because a solution is increasingly urgent, but also because this is a good example of a problem that can only be solved with the participation of the scientific community, government agencies, affected communities, and other stakeholders. In this assembly, therefore, by bringing together selected leading researchers and policymakers whose fields touch on this important area, we hope to catalyze and coordinate efforts towards approaches to the possible solution of this problem.

The workshop will consist of two sessions. The morning session will touch on background papers on the problem in the concerned areas. On the other hand, the afternoon session will focus on providing approaches to possible solutions, reviewing the remediation of toxic wastes using plants, microorganisms, and chemicals. Although the focus is on the use of living organisms to degrade toxic waste into harmless forms, we also have to take a look at other efforts, such as chemical approaches, as a background for bioremediation, which is supposed to be environment-friendly.

As a major output of the workshop, we look forward to initiating efforts towards putting up a research proposal (or proposals) and submitting it to international agencies for funding.

There are several components of bioremediation that we can look at (Ref. National Accelerated Bioremediation Research (NABIR) program of the United States Department of Energy):

Biogeochemistry: Aims to understand the fundamental biogeochemical reactions leading to long-term immobilization of toxic and hazardous wastes (THW).

Biotransformation: Attempts to understand the mechanisms of phyto/microbially mediated transformation of THW in the environments leading to *in situ* immobilization and long term stability.

Community Dynamics and Microbial Ecology: Intends to determine the potential of natural microbial communities to immobilize THW.

Biomolecular Sciences and Engineering: Provides a knowledge base at the biomolecular level of processes leading to the *in situ* immobilization of THW by indigenous subsurface microorganisms.

Bioremediation and its Societal Implications and Concerns (BASIC): Aims to identify and explore societal issues associated with bioremediation.

These are the challenges for us today.

In the afternoon session, participants will be asked to form three groups according to their areas of expertise and interest. The three groups will be:

1. Phytoremediation
2. Health and societal issues
3. Microbial bioremediation

Each of the groups will be tasked to tackle the following issues/questions during the workshop:

1. **What are the compelling issues that we need to address? Can we prioritize?**
2. **What are the possible approaches that we can use to address these issues? Is the approach versatile? (Can the method address more than one pollutant?)**
3. **What strategy can we devise to come up with a winning competitive research proposal? Will the resulting technology be energy-efficient? Is it environment-friendly?**
4. **What are the possible funding agencies for these types of research?**
5. **What are the different institutions and government agencies that can potentially get involved in these research projects?**

With the very informative papers of our speakers, the learned inputs of our participants representing a wide variety of disciplines, and, as our NAST President has said, the inspiration of Hon. Gozun, the DENR Secretary, I am sure this gathering of the best minds in the field of toxic and hazardous waste bioremediation will be a most fruitful and successful one. Thank you.

Environmental Assessment of Areas Affected by Hazardous Wastes

Leah Aurea U. Texon
Engineer, Environmental Management Bureau
Deparment of Environment and Natural Resources

I. Hazardous Waste Management in the Philippines

The Philippines has enacted Republic Act No. 6969 known as the Toxic Substances and Hazardous and Nuclear Waste Control Act of 1990. Under this act, the EMB-DENR is mandated to regulate the generation, transport, import, storage and treatment of toxic substances and hazardous wastes in the country.

To minimize the impact of toxic substances, the EMB-DENR has issued a priority list of chemicals that are known to be toxic and have detrimental effects on the environment. At present, there are 28 chemicals under the list of priority chemicals.

The DENR has also issued control orders for chemicals, namely, mercury, cyanide, ozone-depleting substances and asbestos. The main aim of the CCO is to regulate high-risk chemicals in the Philippines so that the danger to human health and the environment is reduced. Chemicals under CCO require subsequent phaseout or substitution with less toxic chemicals. Under the CCO, the manufacture, transport, storage and use of these chemicals require permits from the Department.

Under RA 6969, the EMB likewise regulates the generation, transport, storage and treatment of hazardous wastes. DAO 29 (implementing rules and regulations of RA 6969) provides a List of Hazardous Wastes .

II. Report on Hazardous Waste Generation

In 2000, there was a JICA-funded project entitled "The Study on Hazardous Waste Management in the Republic of the Philippines" (Phase I). The study aimed to develop a framework plan for hazardous waste management in the Philippines. An inventory of hazardous waste generation in the country was also conducted based on 721 industries registered with the EMB in 2000. At present, there are 2,400 industries registered as hazardous waste generators (EMB Database).

In the study conducted by JICA , there was a reported generation of 278,000 tons of hazardous wastes from 721 industries (Table 1). Sixty-seven percent of the generators are located in the CALABARZON area and are mainly from the manufacturing industry, namely, fabricated metal products and chemicals. From the list of generated hazardous wastes, it was observed that the generation of lead compounds, which fall under the category of inorganic chemical wastes, was high. It was recommended that the recovery or treatment of wastes containing lead be further looked into by the EMB. The generation of alkali wastes was also noted to be high in particular sludge containing heavy metals from wastewater treatment facilities.

During the survey and plant visits conducted by the JICA study team, the following observations were noted:

a. Large amounts of copper sludge generated by the semi-conductor industry
b. Existence of local recyclers of solder dross, which runs counter to the worldwide trend of banning the use of solder dross
c. Widespread use of trichloroethylene by the semiconductors industry and its conversion to isopropyl alcohol
d. Poor occupational health standards practiced by local treaters and recyclers
e. ISO 14001 certification of 28% of the 721 generators, and pending applications of an additional 38%
f. Improper identification of hazardous wastes by generators, treaters and transporters

Table 1 presents the type of wastes generated, while Table 2, which tabulates the geographical location of hazardous waste generators, shows that the majority of these are located in the CALABARZON and NCR, areas where most manufacturing industries are located.

Table 1 Hazardous Waste Generation Amount by Type of Hazardous Wastes

Class	Sub-Category	Generation Amount (tons/year)	
Plating Wastes			
A101	Discarded plating solutions and salts with a cyanide concentration of less than 200 ppm	10622	
	Discarded heat treatment solutions and salts with a cyanide concentration of less than 200 ppm		
A103	Plating solutions and salts containing cyanide at a concentration exceeding 200 ppm	171	
	Heat treatment solutions and salts containing cyanide at a concentration exceeding 200 ppm		
A105	Complexed cyanide solutions and salts	166	
A199	Other cyanide wastes arising from the plating and heat treatment industries	273	
Total		11233	4.0%
Acid Wastes			
B201	Sulfuric acid	19373	
B202	Hydrochloric acid	5516	
B203	Nitric acid	80	
B204	Phosphoric acid	10	
B205	Hydrofluoric acid	221	
B206	Mixture of sulfuric and hydrochloric acids	245	
B207	Other inorganic acid	240	
B208	Organic acids	579	
B299	Other mixed acids	637	
Total		26900	9.7%
Alkali Wastes			
C301	Caustic soda	10489	

Class	Sub-Category	Generation Amount (tons/year)	
C302	Potash	24	
C303	Alkaline cleaners	2108	
C304	Ammonium hydroxide	5	
C305	Lime slurries	4889	
C306	Lime-neutralized metal sludge	38072	
C399	Other alkaline materials	512	
Total		56099	20.2 %
Inorganic chemical wastes			
D401	Non-toxic salts	2216	
D402	Arsenic and its compounds	4012	
D403	Boron compounds	4	
D404	Cadmium and its compounds	2	
D405	Chromium compounds	6180	
D406	Lead compounds	28641	
D407	Mercury and mercuric compounds	1088	
D499	Other salts and complexes	25632	
Reactive chemical wastes			
D501	Oxidizing agents	88	
D502	Reducing agents	0	
D503	Explosive and unstable chemicals	138	
D599	Highly reactive chemicals	121	
Total		68103	24.5 %
Paint/Resins/Lattices/Inks/Dyes/Adhesives /Organic Sludge			
E601	Aqueous-based	932	
E602	Solvent-based	329	
E699	Other mixed	13455	

Class	Sub-Category	Generation Amount (tons/year)	
Total		14769	5.3%
Organic solvent			
F701	Flash point >61 degrees Celsius	120	
F702	Flash points >61 degrees Celsius	1120	
F703	Chlorinated solvents and residues	741	
Total		2216	0.8%
Putrescible/Organic Wastes			
G801	Animal/abattoir waste	7508	
G802	Grease trap wastes from industrial or commercial premises	108	
G899	Others	22972	
Total		30588	11.0 %
Textile			
H901	Tannery wastes	1	
H999	Other textile wastes	80	
Total		81	0.0%
Oil			
I101	Waste oils	10302	
I102	Interceptor sludge	28366	
I103	Vegetable oils	11	
I104	Waste tallow	0	
I105	Oil/water mixtures	9400	
Total		22549	8.1%
Containers			
J201	Portable containers previously containing toxic chemical substances	3499	
Total		3499	
Immobilized Wastes			
K301	Solidified and polymerized wastes	217	
K302	Chemically fixed waste	48	

Class	Sub-Category	Generation Amount (tons/year)	
K303	Encapsulated wastes	251	
Total		516	0.2%
Organic Chemicals			
L401	Aliphatics	817	
L402	Aromatics and phenolics	2307	
L403	Highly odorous	6	
L404	Surfactants and detergents	491	
L405	Halogenated solvents	0	
L406	Polychlorinated biphenyls and related materials	77	
L499	Other organic chemicals	12504	
Total		16266	5.8%
Miscellaneous Wastes			
M501	Pathogenic or infectious wastes	1826	
M502	Asbestos wastes	127	
M503	Pharmaceutical wastes and drugs	11667	
M504	Pesticides	1847	
Total		15467	9.2%
Grand Total		**278,393**	100%

EMB-JICA Study on Hazardous Wastes Management June 2001

Table 2. Hazardous Waste Generation by Region

Region	Generation Amount (tons)	Rate (%)
1 Ilocos	3937	1.4
2 Cagayan Valley	1	0.0
3 Central Luzon	18939	6.8
4 Southern Tagalog	56613	20.3
5 Bicol	97	0.0
6 Western Visayas	7210	2.6
7 Central Visayas	8912	3.2
8 Eastern Visayas	11323	4.1
9 Western Mindanao	60	0.0
10 Northern Mindanao	14178	5.1
11 Southern Mindanao	7771	2.8
12 Central Mindanao	17383	6.2
CARAGA	42	0.0
ARMM	10	0.0
CAR	622	0.2
NCR	131295	47.2
TOTAL	**278393**	**100.0**

EMB-JICA Study on Hazardous Wastes Management, June 2001

Table 3. Hazardous Waste Generators, Employees by Industrial Category

Industrial Code	No. of Generators		No. of Employees		Employees/Generator
Agricultural Industries	6	0.8%	232	0.1%	39
Mining	12	2.4%	6671	2.4%	556
Manufacturing	464	64.5%	226670	80.7%	489
Electricity, Gas and Water	124	17.2%	18778	6.7%	11
Construction	3	0.4%	193	0.1%	64
Wholesale Trade	42	5.8%	2459	0.8%	59
Transportation Services	3	0.4%	969	0.3%	323
Financial Services	2	0.3%	2015	0.7%	1008
Public Administration & Defense	63	8.8%	22906	8.2%	364
Total	**719**	**100.0%**	**280893**	**100.00 %**	**2913**

EMB-JICA Study on Industrial Hazardous Wastes June 2001

The study further showed the following findings:

a. 280,000 tons of hazardous waste are generated per annum by 719 generators
b. 100,000 tons are stored on-site or off-site (destination not identified in the study)
c. It is estimated that there are 1,400 large factories considered to be hazardous waste generators
d. Small-sized recyclers exist, but there are no landfill and thermal treatment facilities
e. 188,000 tons of hazardous waste are generated annually in the study area
f. 51% of this amount is recycled or treated on-site, while 49% or 91, 000 tons per year was identified to be the potential demand for off-site treatment

Table 4 shows the volume of wastes reported to be recycled and treated on-site. Column 6, which was calculated as the hazardous wastes needing off-site treatment, is the difference between the hazardous wastes treated on-site and the volume generated. It was surmised from the study that based on the 719 generators studied, there are about 140,336 tons of wastes that still need treatment. At present, these wastes are stored in the generators' facilities or disposed of illegally.

As indicated in the study, there are 140,336 tons of hazardous wastes that cannot be accounted for. It further estimated that at least 2,000,000 tons of hazardous wastes per annum is generated by about 5,000 industries. This estimate was based on the number of employees. In the initial survey conducted by the JICA Study team, it was not clear whether the wastes were stored or transported without a permit to transport. Thus, the JICA study recommended the establishment of a Model Integrated Facility (MIF). Phase 2 of the Hazardous Waste Management Study was a feasibility study for the establishment of an integrated facility for hazardous wastes.

Table 4. Volume of Hazardous Wastes To be Treated

Hazardous Waste Code	Generation Amount (A)	Recycled Amount (B)	Treatment Needed (C)	On-site Treatment (D)	Off-site Treatment (E)
A	11233	0	11233	9572	1661
B	26900	1087	25813	24667	1146
C	56099	1523	54576	11107	43470
D	68103	33392	34711	2015	32696
E	14769	297	14473	1871	12602
F	2216	850	1366	161	1204
G	30588	8217	22371	9942	12429
H	81	0	81	9	71
I	22549	12540	10009	1377	8632
J	3499	1249	2250	154	2097
K	516	61	455	64	391
L	16226	8649	7577	6151	1426
M	25614	1690	23923	1412	22511
TOTAL	**278393**	**69555**	**208837**	**68501**	**140336**

EMB-JICA Study on Industrial Hazardous Wastes June 2001

Recycled amount (B) The registered volume of recycled hazardous wastes

A- B = C Demand of hazardous wastes treatment

D – on-site treatment (incineration, wastewater treatment facility)

The EMB has been issuing transport permits to registered transporters of hazardous wastes. In the years 2000 and 2001, 112,337 tons of hazardous wastes were issued permits to transport. These wastes are transported from the generators to the recyclers/treaters or storage facilities.

Table 5. Volume of Waste Issued with Permit to Transport

(tons)	2000	2001
Permit for Storage	9346	1,248
Permit for Disposal/Treatment	30752	70,991
Total	**40,098**	**72,239**

Source: HWMS-EQD EMB

At present, there are 48 small- to medium-scale recyclers that treat/recycle hazardous wastes. The process of treatment includes, among others, the distillation of solvents, encapsulation or solidification of sludge, and re-refining and blending of used oil.
Table 6 shows the general process/operations used by local treaters.

Table 6. Mode of treatment of hazardous wastes

Hazardous wastes	**Mode of treatments locally (process)**	**End product**
Used oil	Vacuum distillation , acidification blending/distillation	Asphalt gear oil/lubricating oil
Solder dross	Smelting, molding	Bars and wire, lead ingots
Spent solvent	Distillation	Solvent
Used lead acid battery	Smelting	Lead ingots
Sludge	Recovery/encapsulation	Recovered metals Hollow blocks

Other hazardous wastes are exported to developed countries either for recovery or for disposal. Table 7 shows the list of hazardous wastes that are exported. The requirements under the Basel Convention for Transboundary Movement of Hazardous Wastes are complied with by the exporters prior to the movement of the wastes listed. Export clearance is issued by the EMB-DENR.

Table 7. List of Hazardous Waste Exported

Year	Type of Material	Destination	Quantity	
			Volume	Unit
2000	Wastes containing precious metals	Germany	1000	kg
	Wastes composed of polyetherpolyol, polyisocyanate, and detergent EVA clean	Finland	70,000	kg
	Wastes composed of acetone/resin mixture	Finland	130,000	kg
	Wastes composed of waste grinding sludges and oil/water mixtures	Finland	70,000	kg
	Wastes composed of anaerobic brewery sludges	Hong Kong	100	m3
	Wastes composed of silver epoxy wastes	Japan	3,000	kg
	Wastes composed of copper sludge	Japan	400,000	kg
	Wastes composed of copper sludge	Japan	1,000,000	kg
	Wastes composed of copper ash	Japan	384,000	kg
	Wastes composed of PCB contaminated solid and liquids	Nederland	125,000	kg
	Wastes composed of agrochemical wastes	Nederland	30,000	kg
	Wastes composed of PCB contaminated transformers	Belgium	200,000	kg
	Wastes composed of organic halogenated solvents	Germany	200,000	kg
	Wastes composed of laboratory wastes	Nederland	60,000	kg
2001	Wastes composed of copper sludge	Japan	300,000	kg
	Wastes composed of agrochemical wastes	Nederland	70,000	kg

	Wastes composed of sludge with silver and metal contents	Japan	360	MT
	Wastes composed of silver epoxy wastes	Japan	3,000	kg
	Wastes composed of polyetherpolyol, polyisocyanate, and detergent EVA clean	Finland	70,000	kg
	Wastes composed of waste grinding sludges and oil/water mixtures	Finland	90,000	kg
	Wastes composed of acetone/resin mixture	Finland	130,000	kg
	Wastes composed of inkjet printer ink, water organic solvent, and carbon black dye	Finland	96,000	kg
	Wastes composed of silver epoxy wastes	Japan	700	kg
	Printed wiring board	Japan		
	Wastes composed of copper sludge	Japan	400,000	kg
	Copper sludge	Japan	500,000	kg
	Wastes composed of silver epoxy wastes	Japan	500,000	kg
	Sludge containing silver, copper, lead, iron and aluminum	Korea	20,000	kg
	Inkjet printer ink, water, organic solvent, carbon black dye and sponges containing inkjet	Finland	288,000	kg
	Busted fluorescent lamps	Japan	2,800	kg
	Scrap printed circuit boards and other electronic scraps	Japan	10,000	kg
	Printed wiring board	Japan	80	tons

2002	Wastes composed of silver epoxy wastes	Japan	10,000	kg
	Wastes composed of agrochemical wastes	Germany	200,000	kg
	Wastes composed of laboratory wastes	Germany	300,000	kg
	Sludge containing silver	Japan	500,000	kg
	Sludge containing silver	Japan	240	MT
	Waste composed of N,N-Dimethyformanide formic acid dimethylamide DMF	Finland	90,000	kg
	Sludge containing silver, cooper, lead, iron and aluminum	Korea.	250	Tons
	Waste composed of inkjet printer ink, water, organic solvent, carbon black dye and miscellaneous contaminated waste	Finland	288,000	kg
	Sludge containing copper	Japan	1,000,000	kg
	Waste composed of printed circuit board trimmings	Japan	8,000	kg
	Waste composed of printed circuit board trimmings	Japan	20,000	kg
	Waste composed of printed circuit board trimmings	Japan	7,000	kg
	Waste composed of printed circuit board trimmings and 1200 kg of electronic component scrap	Japan	18,000	kg
	Waste composed of spent solvent and lead solder	Singapore	34,500	kg
	Waste composed of metal scrap	Japan	120	Tons
	Sludge containing copper	Japan	400,000	kg
	Waste composed of busted fluorescent lamps	Japan	2,800	kg

	Waste composed of polychlorinated biphenyls (PCB) transformer/liquids	EFinland	20,000	kg
	Waste composed of agrochemical waste	Germany	300,000	kg
	Waste composed of acetone/resin mixture	Finland	130,000	kg
	Wastes composed of waste grinding sludges and oil/water mixtures	EFinland	105,000	kg
	Waste composed of polyetherpolyol,polyisocyanate and detergent EVA clean mixtures	Finland	70,000	kg
	Waste composed of hydrocarbon and organic solvent contaminated solid waste	Germany	20,000	kg
	Waste composed of polychlorinated biphenyls (PCB) transformer/liquids/capacitor/ contaminated solids	, France	200,000	Kg

III. Hazardous Wastes in Former Military Bases

The Philippine Task Force on Hazardous Wastes in Former US Military Installations (PTFHW) was created under EO 202 on January 18, 2000. The main aim of the Philippine Task Force is to undertake more extensive environmental and human health impact assessment studies and to conduct an information and education campaign program on the bases cleanup efforts. A plan of action of the PTFHW approved in the year 2000 involves the conduct of further studies to assess the extent of hazardous waste contamination and the initiation of environmental remediation and restoration efforts in the area. However, the approved plan of action was not implemented by the PTFHW for budgetary reasons.

For the past 10 years, there has been no reported contamination with hazardous wastes except in the former U.S. military bases. Results of studies conducted in 1996 are presented in Table 8.

Table 8 Summary of Results of Studies conducted in Clark Air Field

Study	Contaminants identified (soil and ground water)	Sites
Environmental Baseline Study	Dieldrin, nitrate, mercury, coliform bacteria Pb, 1,1,2,2-tetracholoethane, 1-2-dichloroethane, 1-2 dichloropropylene, benzene, Cis- 1-2 dichlorothane; dibromochloromethane; ethyl benzene; toluene; trans-1-2 dichohloroethane As, sulfate and coliform bacteria	Wells (operational wells, back-up wells and de-commission ed wells)
Weston International Study	PCB, pesticides and DDT	Power plant
	TPH, Pb, Aldrin	California Bus Line
	Pesticides (aldrin, chlordane, heptachlor, dieldrin)	Motor pool
	Pesticides	Landfill
	Pesticides, TPH	Fire training area
	Insecticides, herbicides, solvents	Civil engineering entomology
	TPH, Pb	Motor pool
	Fuel, solvent, adhesives	Fuel system repair
	PCB	Wagner aviation
	PCB	Hospital

As a result of the study, the CDC has been able to identify priority sites for remediation.

The CDC has likewise conducted several studies, namely:

- site characterization study
- geophysical study of asbestos landfills
- environmental baseline study
- radiological survey
- health impact assessment
- mobile laboratory
- site remediation

The Clark Development Corporation (CDC) is currently implementing a study entitled "Potential Pathways of Known Developmental Toxicants in Childbearing Women". Environmental samples (i.e., air, water, soil and food grown in the area) are collected and analyzed. The study is implemented in collaboration with Harvard University. Likewise, another study entitled "A Comprehensive Water Resources Study" for 15 monitoring wells has been concluded. The results of this study will be reported by the CDC.

IV. Related Projects implemented by the DENR

To address the issue of persistent organic pollutants, which was the main subject of the Stockholm Convention signed by the Philippines in 2002, we are now implementing the GEF UNDP Project entitled "Philippine POPS Enabling Project". One of the activities of this project is to conduct a full inventory of PCB and PCB wastes in the country. This project is funded by the GEF to assist the Philippines in the implementation of the Stockholm Convention on POPs. The Convention aims to eliminate the use of in-place polychlorinated biphenyl (PCB)-containing equipment by the year 2025 and make best efforts to identify, label and remove from use equipment containing more than 50 ppm of PCB.

The DENR will likewise be implementing a UNIDO/UNDP Project that aims to destroy PCBs using non-combustion technology. Under this project, the Global Environmental Facility (GEF) shall provide an initial investment cost of five million dollars ($5 M) for the destruction facility.

The proposed project will be utilizing the Eco Logic International Inc. Gas Phase Chemical Reduction Technology (GPCR) which can treat a variety of hazardous wastes including PCB contaminated soils, transformers, capacitors, organochlorines and other persistent organic pollutants. This project will only be concerned with PCB transformers and capacitors.

V. Recommendations

The hazardous wastes generated, as well as the local technologies used to treat/recycle these wastes, can be surmised from the JICA study. The scientific community can assist the government as well as the industry in providing technical assistance, particularly in the development and/or review of local technologies for the treatment of hazardous wastes. It was estimated in the study that two million tons of hazardous waste will be generated by 5,000 hazardous waste generators. In the absence of an integrated facility for hazardous wastes, the management of this volume will pose a problem to the environment. Thus, there is a need to strengthen collaboration between the government and the academe to address the issue of hazardous wastes in the country.

References:

EMB-JICA Study on Industrial Hazardous Waste Management in the Philippines, June 2001.

Weston International Study, 1997.

Philippine Task Force for Hazardous Wastes in Former Military Bases UNIDO/UNDP Project Brief.

RA 6969 Implementing Rules and Regulations.

The Environment as a Determinant of Children's Environmental Health: An Emerging Concern

Irma Makalinao
Associate Professor of Pharmacology and Toxicology
University of the Philippines College of Medicine

"Stepping into the new century can hardly be done without celebration and new visions for the future. But we who work to protect the rights of children should also go into it with anguish and courage.
Caroll Long, Acting Regional Director, UNICEF

There is a growing concern on how the environment impacts the health of children who are considered to be a very vulnerable population. Preliminary information shows that children living in highly contaminated areas are more likely to reflect toxicity induced syndromes, higher rates of infectious disease, immune system disorders and lower intelligence scores. One of the confounding variables in establishing the link between environment and health effects is the presence of malnutrition. Certain nutritional deficiencies may affect how toxic metals can be absorbed. For example, in the presence of inadequate calcium stores, children will absorb more lead, which is subsequently stored in the developing skeletal system.

In dumpsites, where stockpiles of garbage can be found, it is possible that a toxic gas fume such as hydrogen sulfide gas (H_2S) may be inhaled. This gas is often described as having a rotten egg odor. When the H_2S level exceeds 100 ppm people develop anosmia and the warning signal disappears. Later on as the level approaches 500 ppm, the knockdown phenomena may be observed.

This lecture will highlight the studies being conducted by the Department of Health together with the National Poison Control and Information Service.

Metals are neither created nor destroyed, they can only be transformed. For example, mercury can still be detected both from human and environmental samples in Palawan despite the discontinuation of mining operations. Clearly, one of the metals that is fast getting the same attention as lead is another neurotoxicant which is mercury. More data are emerging showing that, similar to lead, it is possible that mercury may not have a true "no observable adverse effect level" and thus may potentially be harmful to children even at low levels. There are many lessons that we can learn from the tragedy called Minamata disease that has resulted from exposure to methyl mercury.

In the Philippines the small-scale mining industry contributes to the different ways by which people can be exposed to mercury. Artisanal gold mining activities using mercury proliferated in various parts of the country since the early 1980's. In Southern Philippines, a small-scale gold processor is estimated to use 1 kg/week or an average 52 kg/year of mercury. It is estimated that about 30 kg gold/day can be produced. An estimated 140 tons of mercury flux has been dumped directly into the river systems from small-scale gold mining operations in one of the gold rush areas in the country. Adolescents who work often lack the proper protective equipment, resulting in greater exposure to mercury.

Years ago, a paper that I submitted on thermometer bulb ingestion for a medical conference was rejected because according to the textbooks, metallic mercury is not absorbed in the gastrointestinal tract. Our findings, however, have shown that the amount of mercury absorbed may pose a potential risk. This has led to suggestions at the Philippine General Hospital that mercury thermometer bulbs be replaced with less toxic or hazardous materials.

In another study a cross sectional health assessment was done to assess the environmental health impact of mercury among small children living near a gold processing plant. Earlier the community complained of the offensive odor and the noise that the processing operation creates. It was observed that children suffered from very non-specific problems such as rapid fatigue, stomachache, pallor and varying degrees of malnutrition. A well-known case is that of an elementary school in Tagum built after the boom in the gold industry, in which alarmingly high levels of mercury in the blood were observed. One problem in the field of environmental health is the difficulty in proving the link between the toxicant and the outcome, whether it is diarrhea, pneumonia, learning disability, etc. The children who were examined had short stature, gingival discoloration, cervical adenopathy, low weight for height and dermatological abnormalities. This DOH-NPCIS collaborative study further showed significant neurological findings. Cranial nerve abnormalities were seen in 17% of children. Of these 23 (6.9%) had deficits in cranial nerve VIII, 10 (3%) in cranial nerve II and 8 (2.4%) in cranial nerve I. Seventeen (5%) of the schoolchildren had sensory deficits while abnormalities in the deep tendon reflexes were observed in a similar number. Thirteen (3.9%) had cerebellar deficits while 5 (1.5%) had motor nerve abnormalities. In 1998, total blood mercury levels among the Apokon school children revealed a mean $\pm$ S.D of 3.82 $\pm$ 4.58 ug/L as seen in Table 1.

Table 1. Hair and Blood Mercury Levels Among School Children Near a Gold Processing Area in Apokon, Davao Del Norte 1998

Parameter	**Total Mercury**		**Methyl Mercury**		**% Methyl Mercury**	
	Range	Mean +/- SD	Range	Mean +/-SD	Range	Mean +/-SD
Blood (ng/L)	0.757-56.88	3.82+/-4.58	1.36-46.73	6.00+/-8.26	26.4-99.22	76.45+/-22.74
Hair (ug/g)	0.332-20.393	0.99+/-1.6	0.191-18.469	0.799+/-1.45	29.87-99.2	79.76+/-12.77

Based on the Department of Health Briefer, in 1969 a copper mine operated in the island of Marinduque with a capacity of 15,000 tons per day. Five years later, this expanded to about 30,000 tons per day. Over the years, 779.6 million kilograms of copper metal, 23.9 million grams of gold and 127.9 million grams of silver have been produced. The San Antonio copper ore body has an estimated mineable reserve of 198 million tons of copper ore equivalent to a potential 20-year operation. In March 24, 1996, it was estimated that 3 to 5 million cubic meters of mine tailings leaked from a plugged drain tunnel from the Mt. Tapian pit.

The municipal health officer of Sta. Cruz in March 1977 requested the Department of Health to conduct a community health assessment due to an increasing prevalence of hematological-related illnesses among the residents. A review of records of Santa Cruz from 1977-1996 recorded 85 deaths, with an age range of 3-83 years. There were 40 children in this group. The deaths were attributed to leukemia (72.94%), aplastic anemia (18.82%), some other form of blood dyscrasia, and blood-related ailments like anemia. Among the children examined in 1997, nerve conduction velocity studies showed results compatible with axonal degeneration and blood lead levels ranging from 15-19 ug/dl. These children underwent chelation therapy with dimercaptosuccinic acid (DMSA) after consideration of their clinical manifestation and monitoring of their blood lead levels within a six-month interval. All the necessary precautions were done prior to carefully monitored and supervised chelation therapy. Nutritional rehabilitation, micronutrient supplementation and correction of the anemia were also done. Clearly, there is a need to find the source of the exposure, as prevention is still the key to managing these types of illnesses.

There are many lessons learned from more than 100 years of childhood lead plumbism. It took many years before people accepted that lead is very toxic due to the manipulation of the lead industry. The Center for Disease Control (CDC) lowered its action level from 85 to 10 ug/dL over time as new information on lead toxicity emerged. It took many years before lead was banned in household paints exposing children to paints chips inside their homes. Recent evidence tends to support the position that there is no true "safe level" for lead. Changes in IQ are seen even at levels below 10 ug/dL. Children are more vulnerable to lead from the environment because of their developmental stage, their hand to mouth activity and their tendency to play close to the ground. They absorb about 40-50% of ingested lead, which is eventually stored in the bones. Subsequently when these children become pregnant in the future, they can pass on the lead stored in their bones to the developing fetus. Pregnancy is a good physiologic stressor that promotes the release of lead from the bone compartment. In an effort to resolve the issue in Marinduque and do bioremediation measures, the government is looking at an independent study team to examine the health and environmental issues related to this mining disaster. In the meantime, preliminary control measures to contain dust particles were done by exploring which type of plants can grow in the mine tailings.

Another area of concern is Clark Field in Pampanga. The question is "How much of the illnesses being reported by the residents in CABCOM is due to toxicant exposure or may be attributable to some other causes?" Residents in the area also seem to be very concerned with leukemia, especially in their children. Pediatricians and other health care providers should educate them on the early warning signs so that they can bring the sick for treatment while there is still a chance for cure. There is an ongoing evaluation only for selected contaminants due to budgetary constraints. The biologic markers include lead, arsenic, dieldrin and methylhippuric acid as a surrogate marker for benzene exposure. Dieldrin was one of the organochlorines used many years ago. Environmental sampling of air, water and soil is likewise being done.

This paper presented a few examples of how children are potentially chronically exposed to "toxics' in the environment at levels not necessarily known to cause acute poisoning. We must bear in mind that "because children have more future years of life than do most adults, they have more time to develop any chronic disease that may be triggered by early environmental exposures." Internationally, there is mounting concern for children's environmental health. Political, social, economic and even spiritual factors are determinants of children's environmental health. While people talk about building the "science" of this emerging field, we must also remember that even if the evidence is not yet complete as long as there is some evidence of harm, we should employ the precautionary principle.

Our children cannot make choices about the environment is which they live, learn and play. It is up to us adults to make the right decisions to ensure that they are protected. We must not find ourselves conducting "a vast toxicological experiment in which our children and our children's children are the experimental subject." With this, let me say that it is our duty to protect our children because they do not have the capacity to protect themselves. We need to communicate the risks to the policymakers. The scientists, academicians and people in the technical committee will have to present their findings so that the necessary steps can be taken. Hopefully, we can make a difference in the lives of our children.

Disclaimer:
Please note that the studies cited are from collaborative work being conducted by the Department of Health and the National Poison Control and Information Service of the University of the Philippines. They must not be used without consent by the investigators and they do not constitute legal evidence. They represent work in progress at the time of this presentation.

CHEMICAL REMEDIATION OF TOXIC AND HAZARDOUS WASTES

LENI L. QUIRIT, MA. PYTHIAS B. ESPINO AND JAMES A. VILLANUEVA

Professors

Institute of Chemistry

UP Diliman, Quezon City

Sheer and Harris (1982, 1999) report a "happy accidental" chemical remediation of a 'lifeless' part of the Potomac River – a victim of acid drainage from abandoned coal mines. As the river passes a paper mill and a sewage treatment plant, the pH rises from an acidic, lethal value of 4.5 to a neutral value of 7.2, at which fish and plants thrive. This is due to the reaction of CO_2 (from bacterial respiration at the sewage treatment plant) with the calcium carbonate effluent exiting from the paper mill. The resulting soluble bicarbonate neutralizes the acidic river and restores life downstream of the plant.

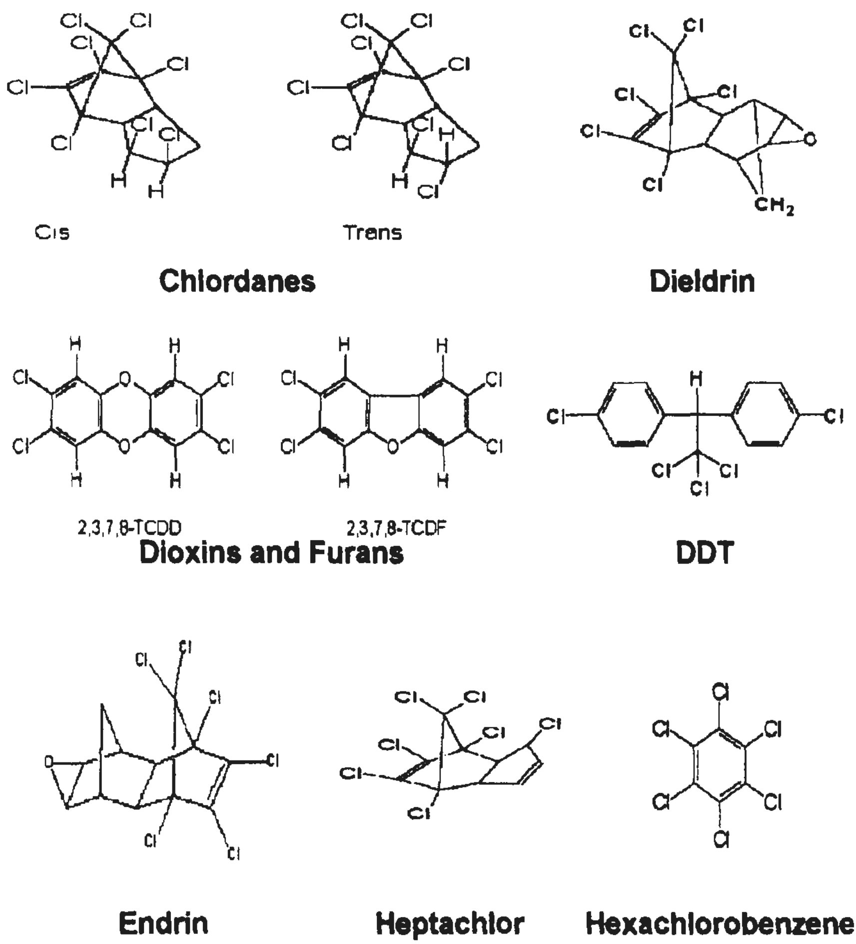
Unfortunately, chemical remediation of most toxic and hazardous wastes (THW) is not as easy as the above case. Examples of these 'difficult' wastes are:

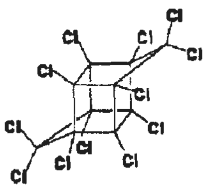
> Persistent organic pollutants (POPs) - chlorinated organic compounds that are intentionally (e.g. pesticides) and unintentionally (e.g. dioxin) produced. These are generally semivolatile and fat-soluble, hence their persistence in the environment and potential bio-accumulation in living organisms, with concomitant harmful health effects. Some of these compounds are shown in Fig. 1 below.
>
> Other organic compounds such as BTEX (benzene, toluene, ethylbenzene and xylene), which are part of a broader class called VOC's (volatile organic compounds), perchloroethylene, trichloroethylene, and polyaromatic hydrocarbons (PAHs).
>
> Metal pollutants (e.g. Pb, Cd, Hg)
>
> Combustion-generated air pollutants (such as NOx, SO_2, VOC's)

Traditional chemical remediation technologies are: deep-well injection, incineration, cement kilns and the landfill cap system. The most commonly used of these is <u>incineration</u>.

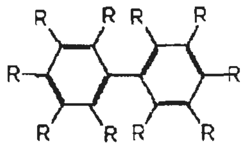
Chemical waste materials are fed into an incinerator at high temperatures (870°C to 1200 °C). Modern incinerators (using high temperatures and oxygen-enriched atmospheres) provide removal efficiencies of up to 99.9999%. However, most incinerators produce by-products such as dioxins and furans.

Figure 1 POPs Compounds

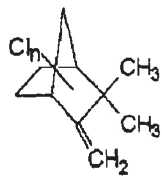




Mirex



PCBs



Toxaphene

New technologies for the remediation of THW's (some of which are discussed below) are (Rahuman et al., 2000):

Supercritical Oxidation
In Situ Chemical Oxidation
Advanced Oxidation Processes
Solvated Electron Technology
Chemical Reduction Reaction
Dehalogenation Processes
Molten Metal Pyrolysis
Molten Salt Oxidation
Plasma Arc
Electrochemical Processes
Catalytic Hydrogenation
Solvent Extraction-Chemical Dehalogenation-Radiolytic Degradation
Solar Detoxification-Photochemical Degradation
Thermal Desorption Integrated Technologies
New Remediation Technologies for Combustion-Generated Air Pollutants
Biological Technologies

In Situ Chemical Oxidation

Media contaminated with chlorinated solvents [such as perchloroethylene (PCE), trichloroethylene (TCE), vinyl chloride (VC)] and other organic contaminants [such as methyl tert-butyl ether (MTBE), polyaromatic hydrocarbons (PAH), benzene, toluene, ethyl benzene and xylene (BTEX)] are injected with oxidants. The oxidants react with the contaminants producing innocuous substances such as CO_2, water and inorganic chloride.

An oxidant which is particularly favored for the destruction of chlorinated aliphatic compounds is potassium permanganate. The pertinent reactions are:

$$C_2Cl_4 + 2MnO_4^- \rightarrow 2CO_2 + 2MnO_{2(s)} + Cl_2 + 2Cl^-$$
$$C_2Cl_3H + 2MnO_4^- \rightarrow 2CO_2 + 2MnO_{2(s)} + 3Cl^- + H^+$$

Advanced Oxidation Processes (AOPs)

This method utilizes oxygen, hydrogen peroxide, titanium dioxide, UV light, electrons, iron or other oxidizing agents to produce free radicals in the degradation of chlorinated organic compounds. In electrochemical peroxidation for example, free radicals are generated from Fenton's reagent, hydrogen peroxide, electricity and steel electrodes to indiscriminately oxidize organic matter in the waste material.

Example : Oxidation with Fenton's Reagent

$$Fe^{+2} + H_2O_2 \rightarrow Fe^{+3} + OH^- + \bullet OH$$
$$RH_{(\text{Organic Contaminant})} + \bullet OH \rightarrow H_2O + \bullet R$$
$$\bullet R + Fe^{+3} \rightarrow Fe^{+2} + \text{Oxidized Product}$$
$$\bullet R + \bullet R \rightarrow \text{Dimer Product}$$
$$\bullet R + Fe^{+2} \rightarrow Fe^{+3} + RH$$

(Free radicals oxidize organic matter; organic radicals may be oxidized, dimerized or reduced; and Fe^{+2} is regenerated to allow redox chain reaction propagation.)

The active ingredient in all AOPs is the hydroxyl free radical (•OH). The main use of this technology is the purification of wastewater contaminants which are resistant to ordinary oxidants like ozone and to other treatments. •OH must be generated on site (using e.g. Fenton's reagent, O_3/H_2O_2, O_3/uv light, semicon photocatalyst [like TiO_2]/sunlight). The technique is quite expensive and is usually integrated with other methods.

Electrochemical Processes

Two applications (Ibañez et al., 1998) are given below:

1) *Remediation of contaminated subsurfaces (groundwater and soil)*

This is frequently a very time-consuming and costly process. In the electrochemical method, suitable anodes and cathodes are strategically placed in the ground, and an electric field from a DC source applied. Liquid in the soil pores moves along the potential field to collection wells (by electroosmotic transport). In addition, H^+ ions (produced in the anode plus from direct injection of non-polluting acids) can solubilize metal and salt pollutants and protonate organic pollutants. These promote their migration across the electric field and speed up their removal.

Electroosmotic flow is more powerful than hydraulic pressure alonc (usually used in *in situ* bio and chemical remediation) since the latter encounter difficulties in fine-grained solids. Electroosmotic flow is independent of pore size

The process can remove metal ions (Cd, Cr, Pb, Hg, Ni, Cu, Zn, U), arsenic, sulfates and nitrates, acetate, phenol and pentachlorophenol, benzene, toluene, trichloroethylene and m-xylene, and petroleum and polycyclic aromatic hydrocarbons.

2) *Remediation of dye-containing aqueous waste streams*

Billions of liters of this type of waste are generated per day from textile mills and dye production plants. The dyes cause environmental problems by absorbing light and interfering with fundamental aquatic biological processes. Also, some dye compounds and intermediates are toxic.

Drawbacks of ordinary chemical treatment are addition of more chemicals and the voluminous precipitates formed. Bioremediation has also been found not very effective for textile effluents.

In the electrochemical technique, corrodible anodes (Fe or Al) produce polyvalent cations which react w/ OH^- from the cathode, producing insoluble hydroxides which adsorb the dyes. Electrolysis gas bubbles carry the pollutant to the top for easier concentration, collection and removal. The solid sludge produced is more compact than sludges obtained by ordinary chemical methods.

Chemical Reduction Reaction

This treatment process involves a chemical reduction of organic compounds by hydrogen in the gas phase at elevated temperatures (> 850°C). The organic compounds are reduced to methane, hydrochloric acid and other low molecular weight hydrocarbons.

The technique is applicable to all organic contaminants. For example, dioxin and furans react with hydrogen to produce methane, HCl and water. DDT and hexachlorobenzene react with hydrogen to produce methane and HCl.

Methane and low molecular weight hydrocarbons react with water to produce CO and hydrogen to some extent. CO and water react to produce carbon dioxide and hydrogen. The methane-rich gas produced is used as fuel, and HCl is neutralized with caustic soda to form slightly salty water. Dioxins and related compounds are *not formed* since the system prevents entry of oxygen. An oxygen-free atmosphere is ensured throughout the process for safety in the use of hydrogen.

Remediation of Combustion-Generated Air Pollutants
(*Catalytic Converters*)

A reduction catalyst made of platinum and rhodium in contact with NO or NO_2 rips the nitrogen atom out of the molecule and holds on to it, freeing the oxygen as O_2 gas. The nitrogen bonds with the other nitrogen atoms on the catalyst to form N_2 gas.

An oxidation catalyst, made of platinum and palladium, hastens the reaction of CO and hydrocarbons in the exhaust gas with oxygen from air to form CO_2 and H_2O. Catalytic conversion is also used to remediate BTEX and alkane contaminated soil air of gas stations

Indirect 'Remediation' of Combustion-Generated Air Pollutants
(*Reduction by production of cleaner burning fuels*)

Desulfurization of Fuels

Sulfur in fuels is burned in air during the combustion process, producing sulfur dioxide. The dioxide further reacts with oxygen to form sulfur trioxide which, upon reaction with water, produces sulfuric acid, one of the main components of acid rain.

Most of the sulfur in coal and petroleum is in the form of heterocyclic organic compounds. The traditional technology used in the removal of sulfur is catalytic hydrogenation. The process generally uses cobalt/molybdenum or nickel/molybdenum on alumina at high temperature and high pressure. The aromatic compounds become saturated and naphthenic rings are opened. The process is expensive and produces hydrogen sulfide and heavy metals.

Alternative desulfurization technologies are:

Phillips S Zorb Technology uses adsorption process to remove sulfur.

Unipure ASR-2 - sulfur species are oxidized to sulfone.

Ultrasonic Selective Oxidation - uses ultrasound waves to remove sulfur.

Biodesulfurization - uses microbes to remove sulfur species. Villanueva et al. (2001) used dibenzothiophene (DBT), a sulfur-containing heterocyclic organic compound, as the model substance for a biodesulfurization study. The biocatalytic process has mild operating conditions and high selectivity, using a reaction chemistry that could only be done biologically.

A number of microbes were found to degrade DBT by cleaving both C-S and C-C bonds. The latter bond breakage would drastically reduce fuel quality. Microbes found to cleave only the C-S (but not the C-C) bonds were *Xanthomonas, Nocardia, Agrobacter, Corynebacterium, Rhodococcus and Arthrobacter*. These transformed DBT to hydoxy biphenyl.

Research is ongoing to improve fuel desulfurization in terms of higher activity and stability of catalysts, less production of heavy metal by-products/wastes, milder but more efficient process conditions and contact optimization of reactor design.

Biodiesel

Biodiesel and byproduct glycerin are produced through transesterification, a process of chemically modifying the molecules of triglycerides (animal fat or vegetable oil) by reacting with alcohol in the presence of heat and catalyst.

Biodiesel fuel is renewable, biodegradable, safe to use, quicker to make and has less emissions. Table 1 shows the emissions reduction data for biodiesel. While fossil fuel takes at least 30 million years to produce, biodiesel can be produced in less than 3 months.

Table 1. Reduction of Environmental Impacts Using Biodiesel*.

POLLUTANTS	PERCENT BIODIESEL IN PETROLEUM						
	0	**1**	**5**	**10**	**20**	**40**	**100**
AIR TOXICS	0.0	0.8	3.8	7.7	16	30	75
PARTICULATES	0.0	0.7	3.4	6.8	18	24	55
CARBON MONOXIDE	0.0	0.5	2.6	5.1	13	18	43
HYDROCARBONS	0.0	0.6	2.8	5.6	11	22	56
CARBON DIOXIDE**	0.0	0.8	3.9	7.9	16	31	78
OZONE POTENTIAL	0.0	0.5	2.5	5.0	10	20	50
CANCER RISK	0.0	1.1	5.5	10.9	27	40	94

***Emissions of using petroleum fuel as basis (Source: USEPA and USDOE, 2002).**
**** CO_2 will be reduced by 100% if biodiesel is from vegetable oil and ethanol.**

Aside from emissions reduction, biodiesel contributes to the remediation of a THW: <u>used cooking oil</u>. Upon heating, cooking oil undergoes chemical reactions, hydrolysis, oxidation and polymerization. Some polycyclic aromatic hydrocarbons (PAHs) in the cooking oil undergo chemical changes, which become carcinogenic, mutagenic and teratogenic. Other hazards associated with used cooking oil are the growth of aflatoxins, which have fatal effects on humans. In some cases, a strong mucus membrane irritant (Schafer, 1996) and carcinogenic compound called acrolein is present in repeatedly heated cooking oil.

Used cooking oil has become a popular feedstock for biodiesel production worldwide. In the US, the "Veggie Van" went all the way from east to west and south to north, covering about 16,000 km (10,000 miles) on 100% biodiesel from used cooking oil restaurants (Tickell and Tickell, 1999). Pacific Biodiesel in Japan started in 1997 utilizing used cooking oil from Kentucky Fried Chicken franchises in Japan. EnviroSafe of Canada began in early 2002 utilizing brown or yellow grease (waste cooking oil from grease traps, renderers and recyclers) for biodiesel production.

A third plus for biodiesel is the potential of its byproduct, crude glycerin, to substitute commercial biodegradation microorganisms. Compost piles added with crude glycerin (from waste cooking oil biodiesel production) have shown enhanced degradation of the compost materials (Cruz, 2002). This can be attributed to the optimum conditions present for enzymatic process of indigenous microbes. Potassium, water, glycerol and fatty acids are already present in the crude glycerin, allowing faster molecule break-up of hydrocarbon atoms.

'Remediation' of Combustion-Generated Air Pollutants
(by Pollution Control Strategies)

Harris (1999) reported a study by Stedman and associates (1996) on remote sensing of air pollutants in traffic-oriented sites. The findings are:

Approximately half of all automobile pollution comes from less than 10% of the cars on the road.

The worst 20% of new cars emit more noxious gases than the best 40% of cars that are 20 years old.

The difference between clean cars and gross polluters in any model year is likely due to poor maintenance or deliberate tampering.

Roadside emission studies showed little benefit from emission inspection programs and from reformulated fuel.

Studies of cars on the road in 1992 found little or no effect from changes such as catalytic converters & closed loop computer systems.

No deliberate step to reduce automobile emissions outweighs the effects of gross polluters.

An automated roadside test, using IR and UV remote sensing measurements, can measure emissions of each passing car for less than \$0.25.

Only gross polluters would receive a notice and the rest of the public will not be inconvenienced.

Although the study was done in the U.S., the use of instrumental analytical chemistry methods (IR and UV remote sensing) as a possible basis for pollution control policies is potentially applicable to the Philippines. The impact, if successful, would be another indirect 'remediation' of combustion-generated air pollutants.

Acknowledgement

The authors are grateful to Dr. Rico O. Cruz (President, EcoEnergy International, Craigmont, Idaho, USA) for the information, data and references on biodiesel.

References

Cruz, R.O. **2002.** "Biodiesel: One of the Simple Responses to the Energy Crises, Environmental Degradation Problems and for Indigenous Peoples Sustainability", in Bioenergy 2002 Conference, Sept. 22-26, Boise, Idaho.

Harris, D.C. **1999.** Quantitative Chemical Analysis (5^{th} ed), W.H. Freeman and Co., N.Y. p. xvii and p. 112.

Ibanez, J.G., M.M. Singh, R.M. Pike and Z. Szafran. **1998.** "Microscale Electrokinetic Processing of Soils", *J. Chem. Ed.*, *75*, 634 - 635.

Ibanez, J.G., M.M. Singh, and Z. Szafran. **1998.** "Color Removal of Simulated Wastewater by Electrocoagulation-Electroflotation", *J. Chem. Ed.*, *75*, 1040 -1041.

Rahuman, M.S.M. Mujeebur, L. Pistone, F. Trifiro and S. Miertus, "Destruction Technologies for Polychlorinated Biphenyls (PCBs)". www.ics.trieste.it/documents/chemistry/catalysis/publications/pops2000/. %5CO$_4$_Rahuman.pdf

Schafer, A. **1996.** "Environmental and Health Concerns at Mercedes Bentz", in Commercialization of Biodiesel: Environmental and Health Benefits, May 21-22, Yellowstone National Park, Montana, pp 199-209.

UNEP Souteast Asis and South Pacific Regional Report (December **2002**). Regionally Based Assesment of Persistent Toxic Substances. UNEP Chemicals, Geneva, Switzerland, pp. 5 - 16.

Demata, M., Andoy, N., Siringan, A., and Villanueva, J. 2003. *Biodesulfurization of Petroleum by Rhodococcus erythropolis*, **Kimika**, 14, 3-11.

BIOREMEDIATION OF TOXIC AND HAZARDOUS WASTES BY DENITRIFYING BACTERIA

Wilfredo L. Barraquio
Professor
Institute of Biology, University of the Philippines Diliman
Diliman, Quezon City 1101

INTRODUCTION

Wastes coming from domestic, industrial, and agricultural sources are polluting our forests, rivers, lakes, groundwater, and air. Physicochemical and biological measures are being utilized to remedy the destruction of resources that support our existence on this planet. Of the measures, bioremediation offers great potential in cleaning up our environment of pollutants. It is a cost-effective and environment-friendly technology that uses microorganisms to degrade hazardous substances into less toxic or harmless forms.

Aromatic compounds are seemingly the most prevalent organic contaminant in groundwater because of their resistance to aerobic degradation. They are very toxic to man and are known to produce symptoms consisting of respiratory distress, cardiovascular complaints, local skin reactions, etc. Their introduction to the environment may be natural or man-made as a component of fuels through leaking storage tanks or spills and component of effluents from factories. For instance, phenol is not only associated with pulp mills, coal mines, refineries, wood preservation plants, and wastewaters (Schie and Young, 1998) but is also natural compound found as secretions from plants. Aromatic compounds may serve as sources of energy and/or carbon for microorganisms. It is known that the less-soluble aromatic compounds find their way into anaerobic sediments and the addition of oxygen during bioremediation treatment is a problem. The search for electron acceptors other than oxygen to encourage aromatic degradation has therefore, become imperative (Gibson and Hardwood, 2002). Among the many natural electron acceptors commonly found, NO_3 is apparently the best (Bakker, 1977; Hutchins et al., 1991; Häner et al., 1995; Zhou et al., 1995; Häggblom and Young, 1999; Coates et al., 2002; Coates et al., 2003). Many compounds, including the aromatics, have been reported to be degraded by diverse NO_3-reducing organisms particularly denitrifying bacteria

NO_3-containing wastes represent an environmental problem of global significance. Most manufacturing industries generate NO_3 wastes. Because chemically- or biologically-produced NO_3 could serve as fertilizer, the farming industry is considered the largest nitrate polluter of surface and coastal waters and drinking water supplies. NO_3 causes eutrophication of lakes, rivers, bays, and seas which generate algal bloom that leads to hypoxia and destruction of marine fauna (Atlas and Bartha 1998). NO_3-contaminated drinking water can cause blue baby syndrome or methemoglobinemia, which is detrimental to infants and nursing mothers. NO_3 as an electron acceptor is likely to be less expensive than maintaining aerobic conditions at the subsurface (Wilson and Bouwer 1997). As electron acceptor, it is a preferable alternate to oxygen compared to ferric iron, sulfate, and carbon dioxide because its energy yield is close to oxygen (the redox potential of the NO_3/NO_2 is nearer to that of the O_2/H_2O couple than any other couple), is highly water soluble (Wilson and Bouwer 1997), and non-toxic to aquifer microorganisms at concentrations below 500 mg/liter (Hutchins 1991).

This paper is a brief review of denitrifying bacteria as highly potential bioremediation agents for simultaneous treatment of sites contaminated with nitrate and various organic compounds especially the aromatics. Our initial results on the search for phenol-utilizing denitrifying bacteria from various polluted and non-polluted sources that employed a modified method of isolation are also included.

DENITRIFICATION AND DENITRIFYING MICROORGANISMS

Denitrification is one of the major processes of the nitrogen cycle where microorganisms utilize oxides of N (NO_3^-, NO_2^-, NO, N_2O) as alternative electron acceptors in the absence of O_2, in the process generating energy and evolving N_2 into the atmosphere (Knowles 1982). It is one of about four types of nitrate reduction. The pathway of denitrification is shown below:

$$NO_3^- \xrightarrow{1} NO_2^- \xrightarrow{2} NO \xrightarrow{3} N_2O \xrightarrow{4} N_2$$

1 = nitrate reductase (Nar)
2 = nitrite reductase (Nir)
3 = nitric oxide reductase (Nor)
4 = nitrous oxide reductase (Nos)

The membrane bound (Nar and Nor) and periplasmic (Nir and Nos) enzymes involved are sensitive to oxygen but there are reports of denitrification in the presence of oxygen (aerobic denitrification) (Wilson and Bouwer 1997, Scholten et al 1999). Denitrification has attracted much attention due to its agricultural, environmental and ecological importance.

All denitrifying microorganisms are facultative anaerobes that respire with both oxygen and NO_3, at different times or at the same time, as electron acceptors. Oxygen is often unavailable in natural ecosystems because of its rapid depletion in the presence of utilizable organic substrates, low solubility in water, and low rate of transport in submerged environments such as wetland soils and sediments. It is interesting to note that whether oxygen is depleted or not, as long as NO_3 is around, denitrifying microorganisms can proceed with the biodegradation process. They are respiratorily flexible because they can use electron donors that include organic (large to small molecules such as CH_4) and inorganic compounds (H_2, H_2S, Na_2SO_3) (Knowles, 1982; Amaral et al., 1995; Costa et al., 2000; Ergas and Reuss, 2001; Suzuki et al., 2001; Kleerebezem and Mendez, 2002; Waki et al., 2002) and inorganic compounds (e.g. H_2, H_2S, Na_2SO_3). Some denitrifying bacteria can also use natural electron acceptors other than O_2 and NO_3 (Myers and Nealson, 1988, 1990; Krause and Nealson, 1997). Generally, denitrifying bacteria are heterotrophic and are active in environments with poor aeration, abundant organic matter, and sufficient NO_3. Denitrification, however, also takes place under autotrophic conditions and seems to be active where electron donors such as CH_4, H_2, H_2S, and thiosulfate are abundant.

Denitrifying ability is found in all the three Domains of the living organisms, especially in Bacteria (Table 1). Bacteria capable of denitrification are spread among phylogenetically diverse groups. Members include novel and old species, Gram-negative and Gram-positive, spore- and non-spore-forming, halophilic and non-halophilic, non-pathogenic and pathogenic, nitrogen-fixing and non-nitrogen fixing, heterotrophic and chemolithotrophic, non-photosynthetic and photosynthetic, psychrophilic to thermophilic, and culturable and unculturable types. Two denitrifying bacteria from the list are worth mentioning: *Dechloromonas* sp. (Coates et al 2001) and *Shewanella putrefaciens* (Myers and Nealson 1988, 1990; Krause and Nealson 1997). The former is a Gram-negative rod which grows with oxygen and NO_3 as electron acceptors. It was isolated with 4-chlorobenzoate as electron donor from a broad range of environments, and is the first example of an organism that oxidizes benzene to CO_2 and H_2O in pure culture under denitrifying conditions. *S. putrefaciens* was isolated from aquatic environments, sediments, oilfields, aquatic animals, and protein-rich foods. It dehalogenates tetrachloromethane in the presence of different electron acceptors such as O_2, NO_3, NO_2, Mn(IV), Fe(III), fumarate, thiosulfate, trimethylamine oxide (TMAO), dimethylsulfoxide (DMSO), and elemental sulfur.

ISOLATION AND HABITATS OF DENITRIFYING BACTERIA

Heterotrophic nitrate-reducing bacteria especially denitrifiers can be isolated using almost any organic medium with nitrate but there are conditions that must be satisfied for a successful isolation. The level of the medium must be relatively high and an inverted tube must be provided to catch the dinitrogen gas that is produced during denitrification. Further access of oxygen must be prevented. The procedure we developed is a relatively easy procedure which allows conditions in the culture tube to become limiting of oxygen so that the nitrate-reducing bacteria would turn to nitrate as an electron acceptor. There is no need to evacuate and change the gas phase to anaerobic conditions. The procedure capitalizes on the property of nitrate-reducing bacteria as facultative anaerobes, capable of utilizing oxygen and nitrate as electron acceptors. The procedure allows the competitive nitrate-reducing bacteria to predominate and be isolated.

The procedure uses nutrient broth + nitrate (10 mM) + phenol (1 mM) and modified mineral salts + ammonium sulfate (1 g/L) solution + nitrate + phenol as culture media. The media are dispensed into about two-thirds of the cotton-plugged Venoject tubes each with an inverted tube. Upon inoculation, the cotton plugs are replaced with rubber stoppers, then the tubes are incubated statically at 30°C. The tubes are subsequently observed for gas formed in the inverted tubes and the disappearance of nitrate and phenol colorimetrically.

Table 1 shows our initial results on the isolation of phenol-utilizing nitrate-reducing bacteria. We have isolated these organisms from both polluted and non-polluted samples, suggesting that they are ubiquitous. These bacteria were previouisly reported by Tschech and Fuchs (1987), Schie and Young (1998), and Shinoda et al. (2000). According to the literature, denitrifying bacteria can be found everywhere from terrestrial (dryland or wetland) to aquatic (marine or freshwater), non-polluted to polluted, heterotrophic to autotrophic, and cold to hot ecosystems. Novel species of denitrifying bacteria in diverse environments have been detected or isolated either by the molecular or cultural method, respectively. Recent reports utilizing molecular methods of detection indicate the existence of unculturable denitrifiers.

To guide us in the search for the most efficient phenol-utilizing denitrifiers, we determined the utilization efficiencies of the isolates in terms of the amount of nitrate utilized per mmole of phenol and amount of phenol used per mole of nitrate. The results are shown in Table 3. Those isolates possessing higher nitrate-reducing and phenol-utilizing efficiencies were considered as potential bioremediation agents. We have selected those isolates, which are now being studied towards their development as bioremediation inoculants.

BIOREMEDIATION TECHNOLOGIES FOR DENITRIFYING BACTERIA

Bioremediation is a technology that combines a biological system with a non-biological system (design of treatment facility and other mechanical components). Two broad classifications of bioremediation are *ex situ* and *in situ*. The former involves the physical transfer of the contaminated material to another area for treatment, while the latter involves treatment of the contaminated material in place (Atlas and Bartha 1998).

The bioremediation technologies that can be applied to groundwater and soil contaminated with organic compounds and NO_3 using denitrifying bacteria are either *ex situ* or *in situ* treatments as proposed in Figures 1 and 2. Sites contaminated with both organic compounds could be bioremediated simultaneously using denitrifying bacteria. Those sites contaminated with organic compounds, but are nitrate-deficient, should be bioremediated by injecting them with acceptable levels of nitrate solution.

CONCLUSION

Bioremediation is a cost-effective, environment-friendly clean-up technology that harnesses microorganisms to remove toxic and hazardous compounds from the environment. Denitrifying bacteria have a great potential as bioremediation agents for the simultaneous utilization/ degradation of nitrate and various organic compounds including the aromatics. They are desirable bioremediation agents because of the following characteristics: (a) respiratorily flexible, (b) phylogenetically diverse and ubiquitous, hence a better screening and selection process for the most desirable strain, (c) capable of working under either oxygen-deficient or oxygen-sufficient conditions, (d) capable of working under both heterotrophic and autotrophic conditions, (e) suitable for both *ex situ* and *in situ* bioremediation treatments, (f) relatively easy to propagate compared to obligate anaerobes, and (g) capable of degrading a wide variety of compounds. In addition, for nitrate-deficient sites, providing NO_3 at the subsurface is likely to be less expensive than adding O_2, and NO_3 as an electron acceptor is very soluble in water and does not bind to soils. We have employed a modified method of isolating nitrate-reducers, especially denitrifying bacteria that could utilize phenol from polluted and non-polluted sources. Some of these isolates are now being studied towards their development as bioremediation inoculants.

ACKNOWLEDGEMENT

This a personally-funded project. The author thanks Brenda A. Lee and Maricel Salvador for technical assistance.

REFERENCES

Afshar S, E Johnson, S de Vries, I Schroder. 2001. Properties of a thermostable nitrate reductase from the hyperthermophilic archaeon *Pyrobaculum aerophilum*. J Bacteriol 183: 5491- 5495.

Alvarez-Ossorio M, FJG Muriana, FF de la Rosa, AM Relimpio. 1992. Purification and characterization of nitrate reductase from the halophile archaebacterium *Haloferax mediterranei*. Z Naturfor^c 47: 670-676.

Amaral JA, C Archambault, SR Richards, R Knowles. 1995. Denitrification associated with groupsI and II methanotrophs in a gradient enrichment system. FEMS Microbiol Ecol 18: 289-298.

Anjum MF, TM Stevanin, RC Read, JWB Moir. 2002. Nitric oxide metabolism in *Neisseria meningitidis*. J Bacteriol 184: 2987-2993.

Atlas RM, Bartha R. 1998. Microbial Ecology: Fundamentals and Applications. 4th ed. Addison Wesley Longman, Inc. Menlo Park, California.

Bakker G. 1977. Anaerobic degradation of aromatic compounds in the presence of nitrate. Microbiol Lett 1: 103-108.

Brettar I, R Christen, MG Hofle. 2002. *Shewanella denitrificans* sp. nov., a vigorously denitrifying bacterium isolated from the oxic-anoxic interface of the Gotland Deep in thecentralk Baltic Sea. Int J Syst Evol Microbiol 52: 2211-2217.

Chen MY, SS Tsay, KY Chen, YC Shi, YT Lin, GH Lin. 2002. *Pseudoxanthomonas taiwanensis* sp. nov., a novel thermophilic, N(2)O-producing species isolated from hot springs. Int J Syst Evol Microbiol 52: 2155-2161.

Coates JD, R Chakraborty, JG Lack, SM O'Connor, KA Cole, KS Bender, LA Achenbach. 2001. Anaerobic benzene oxidation coupled to nitrate reduction in pure culture by two strains of *Dechloromonas*. Nature 411: 1039-1043.

Coates JD, R Chakraborty, MJ McInerney. 2002. Anaerobic benzene biodegradation-a new era. Res Microbiol 153: 621-628.

Costa C, C Dijkema, M Friedrich, P Garcia-Encina, F Fernandez-Polanco, AJM Stams. 2000. Denitrification with methane as electron donor in oxygen limited bioreactors. Appl Microbiol Biotechnol 53: 754-762.

Ergas SJ, AF Reuss. 2001. Hydrogenotrophic denitrification of drinking water using a hollow fibre membrane bioreactor. J Water Suppl Res Technol 50.3: 161-171.

Eriksson M, E Sodersten, Z Yu, G Dalhammar, WW Mohn. 2003. Degradation of polycyclic aromatic hydrocarbons at low temperature under aerobic and nitrate-reducing conditions in enrichment cultures from northern soils. Appl Environ Microbiol 69: 275-284.

Etchebehere C, MI Errazquin, P Dabert, L Muxi. 2002. Community analysis of a denitrifying reactor treating landfill leachate. FEMS Microbiol Ecol 40: 97-106.

Gibson J, CS Hardwood. 2002. Metabolic diversity in aromatic compound utilization by anaerobic microbes. Annu Rev Microbiol 56: 345-369.

Giuffrè A, G Stubauer, P Sarti, M Brunori, WG Zumft, G Buse, T Soulimane. 1999. The heme-copper oxidases of *Thermus thermophilus* catalyze the reduction of nitric oxide: evolutionary implications. Proc Natl Acad Sci 96: 14718-14723.

Häggblom MM, LY Young. 1999. Anaerobic degradation of 3-chlorobenzoate by a denitrifying bacterium. Arch Microbiol 171: 230-236.

Häner A, P Höhener, J Zeyer. 1995. Degradation of *p*-xylene by a denitrifying enrichment cullture. Appl Environ Microbiol 64: 3185-3188.

Hutchins SR. 1991. Optimizing BTEX biodegradation under denitrifying conditions. Environ. Toxicol. Chem. 10: 1437-1448.

Hutchins SR, GW Sewell, DA Kovacs, GA Smith. 1991. Biodegradation of aromatic hydrocarbons by aquifer microorganisms under denitrifying conditions. Environ Sci Technol 25: 68-76.

Ichiki H, Y Tanaka, K Mochizuki, K Yoshimatsu, T Sakurai, T Fujiwara. 2001. Purification, characterization, and genetic analysis of Cu-containing dissimilatory nitrite reductase from a denitrifying halophilic Archaeon, *Haloarcula marismortui*. J Bacteriol 183: 4149-4156.

Kesseru P, I Kiss, Z Bihari, B Polyak. 2002. The effects of NaCl and some heavy metals on the denitrification activity of *Ochrobactrum anthropi*. J Basic Microbiol 42: 268-276.

Khan ST, Y Horiba M Yamamoto, A Hirashi. 2002. Members of the Family Comamonadaceae as primary poly(3-hydroxybutyrate-co-3-hydroxyvalerate)-degrading denitrifiers in activated sludge as revealed by a polyphasic approach. Appl Environ Microbiol 68: 3206-3214.

Kleerebezem R, R Mendez. 2002. Autotrophic denitrification for combined hydrogen sulfide removal from biogas and post-denitrification. Water Sci Technol 45: 349-356.

Knowles R. 1982. Denitrification. Microbiol Revs 46: 43-70.

Kobayashi M, Y Matsduo, A Takimoto, S Suzuki, F Maruo, H Shoun. 1996. Denitrification, a novel type of respiratory metabolism in fungal mitochondrion. J Biol Chem 271: 16263- 16267.

Kodama Y, K Watanabe. 2003. Isolation and characterization of a sulfur-oxidizing chemolithotroph growing on crude oil under anaerobic conditions. Appl Environ Microbiol 69: 107-112.

Krause B, KH Nealson. 1997. Physiology and enzymology involved in denitrification *by Shewanella putrefaciens*. Appl Environ Microbiol 63: 2613-2618.

Kumon Y, Y Sasaki, I Kato, N Takaya, H Shoun, T Beppu. 2002. Codenitrification and denitrification are dual metabolic pathways through which dinitrogen evolves from nitrate in *Streptomyces antibioticus*. J Bacteriol 184: 2963-2968.

Lee DY, A Ramos, L Macomber, JP Shapleigh. 2002a. Taxis response of various denitrifying bacteria to nitrate and nitrite. Appl Environ Microbiol 68: 2140-2147.

Lee H-W, S-Y Lee, J-W Lee, J-B Park, E-S Choi, YK Park. 2002b. Molecular characterization of microbial community in nitrate-removing activated sludge. FEMS Microbiol Ecol 41: 85- 94.

Myers CR, KH Nealson. 1988. Bacterial manganese reduction and growth with manganese oxide as the sole electron acceptor. Science 240: 1319-1321.

Myers CR, KH Nealson. 1990. Respiration-linked proton translocation coupled to anaerobic reduction of manganese (IV) and iron (III) in *Shewanella putrefaciens* MR-1. J Bacteriol 172: 6232-6238.

Schie PM, LY Young. 1998. Isolation and characterization of phenol-degrading denitrifying bacteria. Appl Environ Microbiol 64: 2432-2438.

Scholten E, T Kukow, G Auling, RM Kroppenstedt, FA Rainey, H Diekmann. 1999. *Thauera mechernichensis* sp. nov., an aerobic denitrifier from a leachate treatment plant. Int J Syst Bacteriol 49: 1045-1051.

Shinoda Y, Y Sakai, M Ue, A Hiraishi, N Kato. 2000. Isolation and characterization of a new denitrifying *Spirillum* capable of anaerobic degradation of phenol. Appl Environ Microbiol 66: 1286-1291.

Shoun H, D-H Kim, H Uchiyama, J Sugiyama. 1992. Denitrification by fungi. FEMS Microbiol Lett 94: 277-281.

Shoun H, M Kano, I Baba, N Takaya, M Matsuo. 1998. Denitrification by actinomycetes and purification of dissimilatory nitrite reductase and azurin from *Streptomyces thioluteus*. J Bacteriol 180: 4413-4415.

Shoun H, T Tanimoto. 1991. Denitrification by the fungus *Fusarium oxysporum* and involvement of cytochrome P-450 in the respiratory nitrite reduction. J Biol Chem 266: 11078-11082.

Suzuki M, ZJ Cui, M Ishii, Y Igarashi. 2001. Nitrate respiratory metabolism in an obligately autotrophic hydrogen-oxidizing bacterium, *Hydrogenobacter thermophilus*. Arch Microbiol 75: 75-78.

Tomlinson GA, LL Jahnke, LI Hochstein. 1986. *Halobacterium denitrificans* sp. nov., an extreme halophilic denitrifying bacterium. Int J Syst Bacteriol 36: 66-70.

Tschech A, G Fuchs. 1987. Anaerobic degradation of phenol by pure cultures of newly isolated Denitrifying pseudomonads. Arch Microbiol 148: 213-217.

Tsuruta S, N Takaya, I Zhang, H Shoun, K Kimura, M Hamamoto, T Nakase. 1998. Denitrification by yeasts and occurrence of cytochrome P450nor in *Trichosporon cutaneum*. FEMS Microbiol Lett 168: 105-110.

Usuda K. N Toritsuka, Y Matsuo, D-H Kim, H Shoun. 1995. Denitrification by the fungus *Cylindrocarpon tonkinense*: anaerobic cell growth and two isozyme forms of cytochrome P-450nor. Appl Environ Microbiol 61: 883-889.

Zhou J, MR Fries, JC Chee-Sanford, JM Tiedje. 1995. Phylogenetic analyses of a new group of denitrifiers capable of anaerobic growth in toluene and description of *Azoarcus tolulyticus* sp. nov. Int J Syst Bacteriol 45: 500-506.

Table 1. Updated list of denitrifying microorganisms.[a]

Genus	Domain	Reference
Achromobacter, Acidovorax Agrobacterium, Alcaligenes, Aquaspirillum, Azoarcus, Azovibrio, Azospira,Azospirillum, Bacillus, Blastobacter, Bordetella, Bradyrhizobium, Burkholderia, Chromobacterium, Comamonas, Corynebacterium, Cytophaga, Dechlorimonas, Ensifer, Flavobacterium, Flexibacter, Frateuria, Halobacterium, Herbaspirillum, Hydrogenobacter Hyphomicrobium, Magnetospirillum, Marinobacter, Mezorhizobium, Microvirgula, Moraxella, Neisseria, Oceanomonas, Ochrobactrum, Paracoccus, Propionibacterium, Pseudomonas, Pseudoxanthomonas, Ralstonia, Rhizobium, Rhodobacter, Rhodopseudomonas, Shewanella, Sphingomonas, Streptomyces, Spirillum, Thauera, Thiobacillus, Thiomicrospira, Thioalkalivibrio, Variovorax, Vibrio, Xanthomonas, Zoogloea	BACTERIA	Anjum et al 2002, Brettar et al 2002, Chen et al 2002, Etchebehere et al. 2002, Kesseru et al. 2002, Khan et al 2002, Kumon et al 2002, Lee et al 2002a, Lee et al 2002b, Eriksson et al 2003, Kodama and Watanabe 2003

Ferroglobus, Haloarcula, Halobacterium, Haloferax, Pyrobaculum, Thermus	ARCHAEA	Tomlinson et al., 1986, Alvarez-Ossorio et al., 1992, Völkl et al., 1993, Vorholt et al., 1997, Giuffrè et al., 1999, Afshar et al., 2001, Ichiki et al., 2001
Cylindrocarpon, Trichosporon, Fusarium	EUKARYA	Shoun and Tanimoto 1991, Shoun et al., 1992, Usuda et al., 1995, Kobayashi et al., 1996, Tsuruta et al., 1998

[a]Because of the large number of references in Domain Bacteria, only those references in the last 3 years were included in this table.

Table 2. Number of denitrifying phenol-utilizing bacterial isolates obtained from various sources.

Source	Number of phenol-utilizing denitrifying isolates
Rice rhizosphere	7
Water and sediment of a lagoon	3
Roots of plants (*Ipomea aquatica* and *Lotus* sp.) growing on lagoon	10
North Harbor sediment	7
Hot spring sediment	3
Tilapia pond sediment	35
Padas (local fermented fish)	2

Table 3. Nitrate-reducing and phenol-utilizing efficiencies of some bacterial isolates in two culture media with phenol.

Bacterial isolate	Nitrate-reducing efficiency (mmole NO_3 per mmole phenol utilized)		Phenol-utilizing efficiency (mmole phenol per mmole NO_3 utilized)	
	Nutrient broth + nitrate + phenol	Mineral salts + ammonium sulfate + phenol	Nutrient broth + nitrate + phenol	Mineral salts + ammonium sulfate + phenol
UFRd8	6.3	8.9	0.11	0.16
UFRd11	9.1	9.4	0.11	0.01
FSa14	9.8	7.4	0.10	0.13
FRd17	8.8	9.1	0.11	0.11
FSnr22	3.4	10.8	0.29	0.09
FSa29	19.2	12. 6	0.05	0.08
FSd30	8.2	8.3	0.12	0.12
FSdnra40	16.1	14.6	0.06	0.07
FRd43	7.7	8.5	0.13	0.12
FRa15	16.0	9.1	0.06	0.11
FSnr1	16.8	14.6	0.06	0.07
L1-3	13.8	13.0	0.07	0.08
L1-3a	8.5	0.2	0.12	5.0
L1-3c11	6.3	7.8	0.16	0.13
L2-6a	7.4	4.1	0.13	0.24
L2-6b	17.7	19.5	0.06	0.05
K1-5a	6.3	3.0	0.16	0.33
K1-5b	18.4	8.5	0.05	0.12
K1-6a	8.7	5.9	0.11	0.17
K1-6b	7.0	12.5	0.14	0.08
K1-9b	11.8	2.3	0.08	0.43
K1-9c	14.3	1.4	0.07	0.71

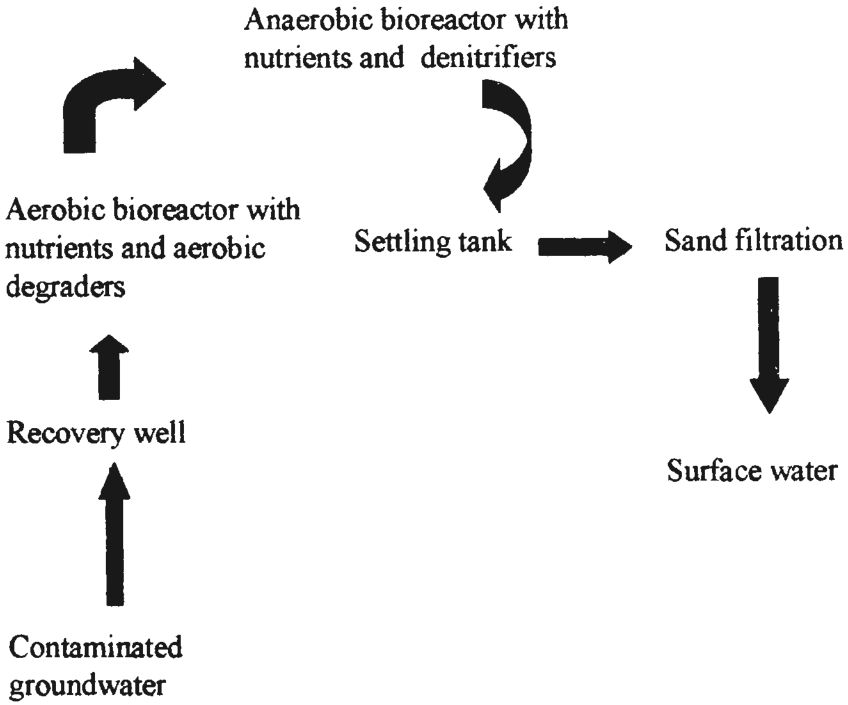


Figure 1. Proposed *ex situ* bioremediation of groundwater contaminated with organic compounds and nitrate (modified from Atlas and Bartha 1998).

REMEDIATION OF TOXIC AND HAZARDOUS WASTES: PLANTS AS BIOLOGICAL AGENTS TO MITIGATE HEAVY METAL POLLUTION

NINA M CADIZ[1] and EDUARDO B PRINCIPE[2]

[1]*Associate Professor, Institute of Biological Sciences, UP Los Baños, College, Laguna*

[2]*Regional Technical Director for Research, Ecosystems Research and Development Bureau, DENR, College, Laguna*

I. Introduction

Plants As Biological Agents to Control Heavy Metal Pollution? The answer is definitely – YES! Green plants root out heavy metals and reduce the movement of contaminants by root adsorbtion. The use of plants to rehabilitate metal-contaminated sites is highly favored because it turns out to be cheaper compared to both physical and chemical methods. Plants also add to the aesthetic beauty of the environment and improve soil conditions which favor the growth of beneficial organisms. This process, which makes use of green plants to clean contaminated soils or to render the toxic ions harmless, is a new and emerging technology called **phytoremediation** (Markert, 1994; Becker, 2000).

Phytoremediation or green technology is of two levels: (1) ***phytostabilization*** is the use of plants to reduce the effects of erosion and human contact, and decrease the environmental impact of toxic wastes, and (2) ***phytoextraction*** is the use of plants to take up contaminants and translocate them to shoots which can later on be harvested for reclamation or disposal.

The present scenario indicates that more than 25% of the soil worldwide is contaminated with toxic heavy metals, making these soils unproductive for plant growth. Heavy metal pollution has already become a major threat to our environment and human health. Toxic metal ions enter the food chain and are transferred to humans and animals, where they cause cumulative and detrimental effects. For instance, cases of exposure to heavy metals or consumption of contaminated food resulting in skin disorders, birth defects, infertility, diarrhea, loss of appetite and renal damage have been reported.

Cleaning up our environment of toxic heavy metal contamination is therefore a global concern. With phytoremediation or green technology, this problem is anticipated to be alleviated.

II. What are heavy metals?

Elements essential for plant growth are grouped into macro and microelements, i.e., those needed by plants in high and low concentrations, respectively. A number of micro-elements are metals such as copper (Cu), zinc (Zn), iron (Fe), and manganese (Mn), which act as cofactors or as parts of prosthetic groups of enzymes controlling a variety of metabolic and developmental pathways in biological systems (Tomsett and Thurman, 1988). Not all metals, however, are essential like lead (Pb) and cadmium (Cd).

Metals are classified in various ways. Metals which produce toxic effects in plants with a specific gravity (or density) greater than 5.0 are classified as "heavy metals" (Lapedes, 1974). However, this classification has been extended to other metals (e.g. aluminum and beryllium) causing deleterious effects even if they do not possess the chemical and physical characteristics of the so-called "heavy metals". Heavy metals form the main group of inorganic contaminants (Alloway, 1990).

III. A. Sources of heavy metal pollution

The occurrence of heavy metals in the environment is widespread. Heavy metal ions occur in soil, water and air. They may exist naturally such as in serpentine soils (Davies, 1991) or as a result of anthropogenic activities. For instance, metal contamination could result from the mining of coal, shale, oil and metallurgical processes.

Toxic heavy metal ions could also enter the soil by the addition of phosphate fertilizers, metal containing pesticides and industrial sewage sludge (Street et al., 1978). The application of pharmaceutical products containing copper (Cu) and zinc (Zn) to plants also result in heavy metal pollution in the environment. Ore smelting, as well as activities of and emissions from stacks of fossil fuel-burning plants contribute to air pollution as well.

In addition, car emissions due to the presence of lead (Pb) additives in **petrol** bring about elevated metal concentration in the air. Thus, plants in close proximity to the highways have been found to contain high levels of Pb in their tissues (Quarles et al.1974).

B. Mine Waste and Tailings Disposal in the Philippines

The system of disposing mine tailings into the sea directly alters the physico-chemical characteristics of the water due to the fine particles of mine tailings and the ionic elements from the heavy metals discharged (Fellizar et al., 1997). Since cadmium, copper, lead, mercury and zinc are present in the discharged materials, the possibility that these heavy metals reach man through the food chain is not remote.

The problem of tailings disposal in the Philippines has existed since the 1950's. In 1977, the annual generation of tailings by mining firms was about 65.7 million dry metric tons (MT). In 1985, mine waste and tailings generated by all mining firms totaled 145.59 million MT. In 1986, mine waste tailings decreased to 90.8 million MT, representing a decrease of 37.6%. A slight increase of 2.76% and 1.05%, however, was observed in 1987 and 1988, respectively. Although the volume of mine tailings and wastes has been significantly reduced from 1985, the subsequent release of these materials into the environment continues to be the main source of land and water pollution (EMB, 1990).

Coastal resources are also affected by the disposal of mine tailings. For instance, the buildup of the Calancan Bay causeway for Marinduque Mining Corporation mine tailings has caused considerable damage to the bay's coastal resources. It is estimated that close to 113 million MT of tailings and wastes have been discharged into the bay from 1975 to 1986, covering about 45-50 sq. km. of the sea floor. This is equivalent to an area of 4,500 hectares (Lingkod, 1988).

IV. Phytoremediation

A. Biological Stabilization

Contaminated soils can be remediated by chemical, physical or biological means (McEldowney, et al., 1993). Many of the remediation technologies available have been shown to be effective and efficient only on a small scale, and have not been demonstrated on a large scale. In addition, physico-chemical strategies to remediate heavy metal contaminated soils render the land useless for plant growth, as they kill the natural flora and fauna of the soil. Heavy metal-contaminated areas are likely to support plant species that would tolerate high concentrations of the toxic ions by concentrating them in their tissues (Cadiz et al., 1999).

In the Philippines, there is no complete and consolidated documentation of heavy metal pollution. Monitoring agencies such as the Department of Environment and Natural Resources have limited information, which is confined to the mining industries and the environmental hazards they have caused. While other bits of information can be found in other agencies like the Bureau of Mines and Bureau of Soils and Water Management, this would still not give a clear picture of the extent of heavy metal contamination in the country.

Several plants have been reported to grow in heavy metal-contaminated sites. The vegetation that develops on serpentine asbestos mine tailings is composed of grasses such as *Lolium perene* (perennial rye grass), *Poa pretensis* (Kentucky bluegrass) and *Elymus junceus* (Russian wildrye). The reclamation of metalliferous areas was made possible using tolerant populations of *Festuca rubra* (red fescue), *Agrostis stolonifera*, lead- and zinc-tolerant species, and *Agrostis tenuis*, which is tolerant to lead and copper.

In the Philippines, a number of plants have been used successfully for bank and slope stabilization. Some of these are *Leucaena leucocephala* (ipil-ipil), *Alnus maritima* (Japanese alder), *Gliricidia sepium* (madre de cacao), *Pithecelobium dulce* (camachile), *Agave cantala* (maguey), and *Cynodon dactylon* (Bermuda grass). Different grasses and leguminous vines (kudzu) were also tried in the dry tailing pond of Island Cement (Diaz, 1979).

B. Vegetative rehabilitation of the mine tailings causeway at Calancan Bay, Marinduque Island: The Marcopper Experience

Area developed and established

Calancan Bay, a natural cove north of Marinduque Island, was used as a discharge point for the tailings resulting from the mining operations of the Marcopper Mining Corporation. Through time, these materials have accumulated to such an extent that at present, a 4.7 km causeway with an approximate total area of 84 hectares, practically divides Calancan Bay into its western and eastern sections.

The total area developed in the causeway, including the mangrove area, was 42.89 ha as of October 1996 (Table 1).

Table 1. Survival of plants in areas developed.

Species	Spacing (m)	Area Developed (Ha.)	Survival (%)
			1996
Bakauan (*R. mucronata*)	1 x 1	13.36	87
Bitaog (*C. inophyllum*)	1 x 4	1.07	79
Aroma (*P. vidaliana)*	1 x 4	14.57	95
Auri (*A. auriculiformis*)	1 x 4	7.14	65
Talisay (*T. catappa*)	1 x 4	3.31	94
Camachile (*P. dulce*)	1 x 4	(0.77)	75
Dapdap (*E. orientalis*)	1 x 4	(0.31)	70
Malapigas (D. umbellatum)	2 x 2	0.96	75
Agoho (*C. equisetifolia*)	3 x 3	1.65	98
Bani (*P. pinnata)*	1 x 1	0.83	81

Total Ave. 82

Total Area 42.89

Portion of the minetailings planted to *Prosopis vidaliana* (aroma).

Plant species planted and success survival

There were ten (10) species planted in the area. A total of 14.57 ha was planted to *Prosopis vidaliana* (aroma), the largest (excluding the mangrove site), followed by *A. auriculiformis* (7.14), *T. catappa* (3.31), *C. equisetifolia* (1.65), *C. inophyllum* (1.04), *D. umbellatum* (0.96), and *P. pinnata* (0.83). About 13.36 ha of the mangrove area was planted to *Rhizophora mucronata*. Planting distance varied among species from 1 x 1 m to 3 x 3 m (Table 1).

The average survival for all plantations is 82% (Table 1). Among the species, *Casuarina equisetifolia* attained the highest survival rate of 98%, while *Acacia auriculiformis* showed the lowest survival rate. *Casuarina equisitifolia*, on the other hand, appears to be the most promising in terms of both survival and growth rate. Although not planted intensively, *D. umbellatum* (malapigas), a native volunteer species in the area, also looks promising for mine tailings. It showed a survival of 75% using cuttings. Despite its being a prolific seeder, the use of potted seedlings was not tried because wildlings of malapigas are scarce and seeds are often attacked by seed borers. Therefore, proper timing for seed collection may result in a high survival rate of potted seedlings.

Table 2. Floristic composition of the causeway, October 1996. Except for ipil-ipil, all species listed are volunteers.

Local/Common Name	Scientific Name	Family
A. TREES		
1. Aroma	*Prosopis vidaliana*	Mimosaceae
2. Ipil-ipil	*Leucaena leucocephala*	Mimosaceae (Introduced)
3. Bayabas	*Psidium guajava*	Myrtaceae
4. Matang-hipon	*Breynia rhamnoides*	Euphorbiaceae
5. Putat	*Barringtonia racemosa*	Lecythidaceae
6. Alagao	*Premna odorata*	Verbenaceae
7. Malubago	*Hibiscus tiliaceus*	Malvaceae
8. Narra	*Pterocarpus indicus*	Papilionaceae
9. Fire tree	*Delonix regia*	Caesalpiniaceae
10.Alibangbang-pula	*Bauhinia* sp.	Caesalpiniaceae
11. Batinong-liitan	*Alstonia parviflora*	Apocynaceae
12. Sampaloc	*Tamarindus indica*	Caesalpiniaceae
13. Hamindang	*Macaranga bicolor*	Euphorbiaceae
14. Anabiong	*Trema orientalis*	Ulmaceae
15. Kusibing	*Sapindus saponia*	Sapindaceae
B. VINES/SHRUBS AND PALMS		
1. Soob-cabayo	*Hyptis suaveolens*	Labiatae

2.	*Tridax procumbens*	Asteraceae
3.	*Allysicarpus vaginalis*	Papilionaceae
4. Lambayong	*Ipomoea* sp.	Convolvulaceae
5. Hagonoy	*Chromolaena odorata*	Asteraceae
6.	*Lantana camara*	Verbenaceae
7.	*Desmodium gangeticum*	Papilionaceae
8.	*Centrosema pubescens*	Papilionaceae
9.	*Callopogonium mucunoides*	Papilionaceae
10.	*Waltheria Americana*	Sterculiaceae
11.	*Passiflora foetida*	Passifloraceae
12. Balabalatungan	*Tephrosia dichotoma*	Papilionaceae
13.	*Corchorus acutangulus*	Malvaceae
14. Banago	*Thespesia populnea*	Malvaceae
15.	*Jasminum bifarium*	Oleaceae
16. Tabon-tabon	*Guettarda speciosa*	Rubiaceae
17. Makahiya	*Mimosa pudica*	Mimosaceae
18.	*Fluggea virosa*	Euphorbiaceae
19.	*Cassytha filliformis*	Lauraceae
20.	*Capparis* sp.	Capparidaceae
21. Cabatiti	*Colubrina asiatica*	Rhamnaceae

22. Dauag	*Mezoneurum latisiliquum*	Caesalpinaceae
23. halobatbat	*Capparis microcantha*	Capparidaceae
24.	*Scaevola frutescens*	Goodeniaceae
25. Buta	*Excoecaria agalloca*	Euphorbiaceae
26.	*Phyllanthus simplex*	Euphorbiaceae
27. Niyog	*Cocos nucifera*	Palmae
28.	*Stachytarpheta jamaicensis*	Verbenaceae
C. GRASSES 1. Talahib	*Saccharum spontaneum*	Gramineae
2.	*Eragrostis* sp.	Gramineae
3. Korokorosan	*Chloris barbata*	Gramineae
4.	*Rhynchelytrum repens*	Gramineae
5.	*Themeda gigantea*	Gramineae
6. Cogon	*Imperata cylindrica*	Gramineae
7. Amorseco	*Chrysopogon aciculatus*	Gramineae

C. Vegetative rehabilitation of abandoned mining areas: The Compostela Valley Experience

Compostela Valley has about 2,171 ha of abandoned mining area. In an effort to rehabitate the area, concerted efforts were done by various government agencies particularly DENR.

Trial plantings of some reforestation and dipterocarp species were done at two abandoned mining sites - one at Camanlangan, New Bataan and Nabunturan, Compostela Valley). Five reforestation species, planted as seedlings, were observed to grow and survived well at Camanlangan (Casidsid, 2002). On the other hand, rooted cuttings of white lauan (*Shorea contorta*), palosapis (*Anisoptera thurifera*), bagtikan (*Parashorea plicata*), and guijo (*Shorea guiso*). were noted to grow equally well, with white lauan showing the highest growth performance (Bautista and Basada, 2002).

V. Screening For Heavy Metal Tolerant Plants

What is wanting in R&D projects such as this is screening for tolerant species. A vast number of plants is yet to be studied. Their mechanisms of adaptation are still poorly understood. The studies of Cadiz, et. al. (1995, 1999) provide basic information as to the tolerance strategies of plants to toxic metals. A quick method of screening for tolerant species was also reported.

There is indeed a dearth of information regarding the expressed characteristics of heavy metal tolerant plants. A continuous screening must be done to catalogue characteristic traits expressed by such plants. The following sections give some information as to the markers of tolerance of some plants to heavy metals at the morpho-anatomical, cellular, molecular and physiological levels.

Despite the ability of some plant species to grow in heavy metal-contaminated sites, a vast number of potential colonizers has yet to be discovered. For the past decade, plant scientists have been searching for species that could clean up contaminated areas. Our inadequate understanding of transport and tolerance mechanisms somehow slowed down phytoremediation as an emerging technology to rehabilitate heavy metal-contaminated soils.

A. Bioassays

Root growth is a vital component of plant growth and development. Plants with vigorous root systems have a greater capacity to exploit soil reserves compared to poorly developed ones. Because roots are sensitive to heavy metals, the response of this vital plant organ to elevated levels of the toxic ions becomes an important consideration in screening for metal tolerant species. The bioassay involves the germination of seeds in varying concentrations of heavy metals. Species or cultivars that showed more than 50% germination percentage are selected and grown further in soil within a certain range of metal levels.

B. Laboratory (or Pot) Scale Trials

Species which are initially screened using germination and root growth bioassays are further studied for tolerance using laboratory scale or pot trials. These plants are treated with solutions containing various levels of heavy metals (Cd, Pb or Zn). Morphological changes attributed to more tolerant species are noted. Characters such as root and shoot growth are also indicators of tolerance.

Rain tree, mangium, mungbeans and alibangbang have been studied for metal tolerance, and were observed to be potential cleaners of sites contaminated with heavy metals (Cadiz, 2002).

C. Field or On-Site Trials

Species previously screened for heavy metal tolerance are planted in heavy metal-contaminated sites for survival and adaptation studies.

D. The Markers And Mechanisms of Tolerance

1. Morpho-anatomical markers

Root growth

The immediate response of plants to increasing levels of heavy metals is reduced growth not only in terms of root length (Fig. 1) but also in terms of root biomass (Fig. 2).

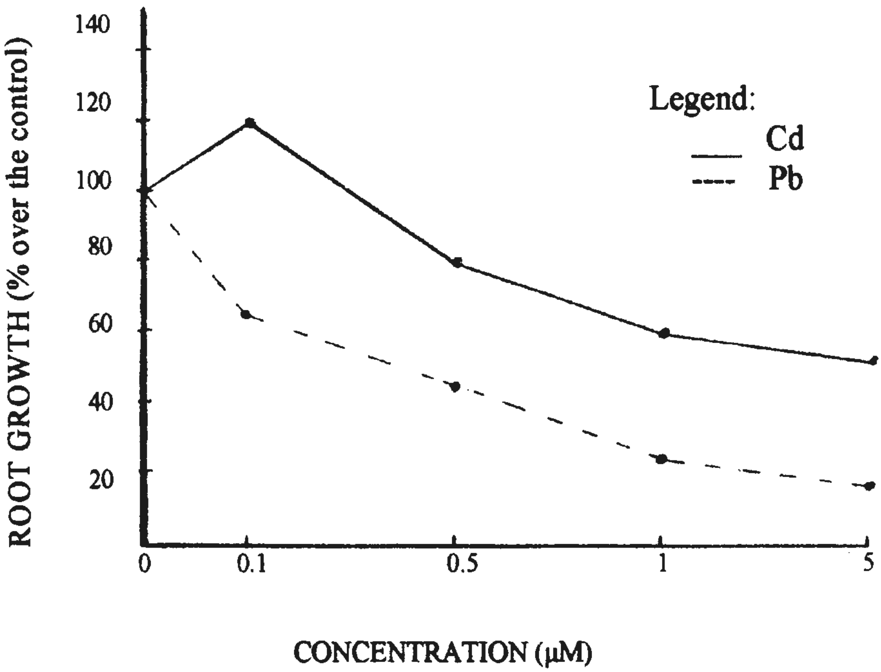


Figure 1. Root growth (% over the control) *of Vigna radiata* cv Pag-asa 1 grown in increasing levels (0, 0.1, 0.5, 1.0, and 5.0 µM) of Cd and Pb for 7 days.

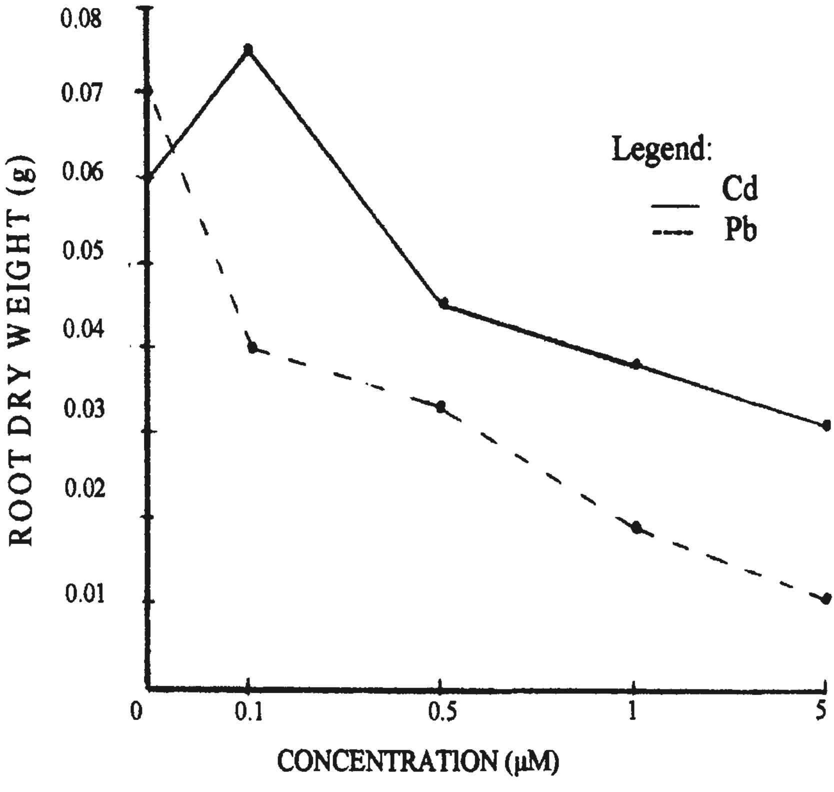


Figure 2. Root biomass of *Vigna radiata* cv Pag-asa 1 grown in increasing levels (0, 0.1, 0.5, 1.0, and 5.0 µM) of Cd and Pb for 7 days.

Other root characters such as meristem length (Fig. 3) are also affected. Roots of more tolerant species, such as mungbean cv Pag-asa 1, form root hairs farther from the proximal boundary of the meristem in contrast with the non-tolerant ones. This could be regarded as a mechanism of the plant to tolerate a given stress by decreasing the surface area for absorption. In addition, plants that tend to tolerate toxic metals produce more lateral root primordial than the non-tolerant ones.

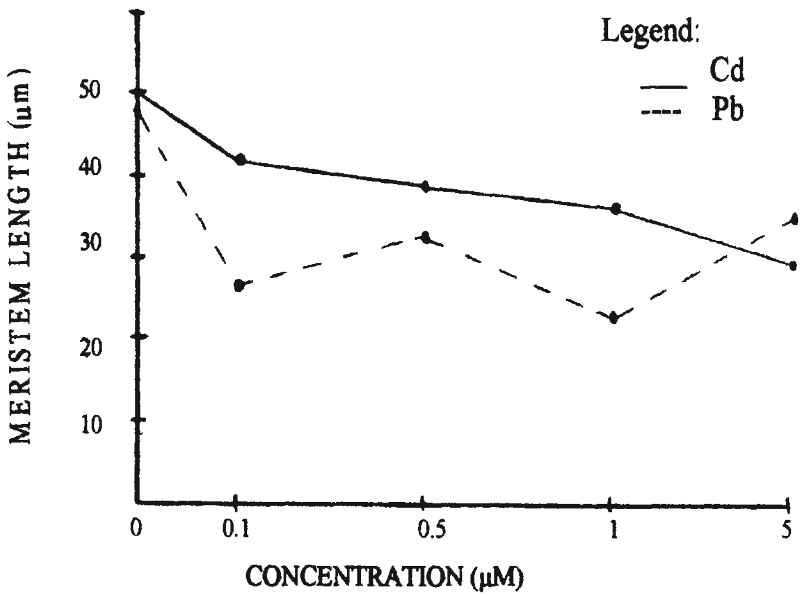


Figure 3. Length of root meristems (μm) *of Vigna radiata* cv Pag-asa 1 grown in increasing levels (0, 0.1, 0.5, 1.0 and 5.0 μM) of Cd and Pb for 7 days.

2. Cellular Markers

The mitotic index (MI), which is measured as the proportion (%) of the number of cells in the mitotic phase over the total number of cells observed in a series of random transects, has been used as an indicator of tolerance to the heavy metals (Cadiz et al., 1999). Other cellular markers that could be used are the total cell area, both cytoplasmic and nuclear.

Species (e.g. *Vigna radiata* cv Pag-asa 1, Table 1) more tolerant to heavy metals exhibit less reduction in mitotic index compared to the non-tolerant ones. This indicates that cell division of tolerant species is not drastically affected by elevated levels of the toxic metal ions.

Table 1. Average mitotic index (%) of 13d old mungbean (Pag-asa 1) grown for 7 days under varying concentrations (µM) of Cd and Pb. DMRT shows that values followed by the same letter (per metal) are not significantly different at 5% level. The values between the MI of the two metals, however, are significant.

	Concentration (µM)					
Heavy Metal	0.0	0.1	0.5	1.0	5.0	Average
Cd	20.1 ^{A}	17.47 ^{B}	12.17 ^{C}	9.2 ^{D}	4.5 ^{E}	12.7 ^{2}
Pb	24.1 ^{a}	21.07 ^{b}	16.67 ^{c}	13.2 ^{d}	18.43 ^{e}	16.7 ^{1}

3. Molecular and Physiological Markers

DNA and protein contents generally decline in plants as a response to increasing heavy metal concentration (Cd, Pb and Zn). However, tolerant species like the grass cultivar of festuca cv Merlin, exhibit lesser reduction in this characters as compared to holy basil (Cadiz, 1998; Cadiz et al., 1999). The observed decline in DNA density in holy basil could be attributed to (1) shift to G1 phase, (2) interference with Feulgen staining, or (3) aneuploidy (loss of chromosomes) as evident in the clumping and margination of chromatin (Cadiz et al., 1999). This has not been observed in Merlin. The gene(s) in festuca conferring tolerance to Cd, Pb and Zn have not been isolated and identified.

4. Compartmentalization of the heavy metals

Tolerant plant species tend to compartmentalize toxic heavy metal ions in various parts of the cells. For instance, Pb is compartmentalized in plant cell walls of the roots. Cadmium is compartmentalized in both cell walls and cytoplasm. Others bind to phytic acid in the cytoplasm. Tolerant plants also tend to synthesize phytochelatins which bind the heavy metal ions thus reducing their toxic effects. This strategy, likewise, reduces the transport of the toxic metal ions to the shoot portion of the plants.

5. Other Markers of Tolerance

a. Stomatal characters

Other characteristics of plants could be used for assessing the level of their tolerance to the heavy metals. One of these is stomatal character. Very few studies on the effects of heavy metals on stomata have been reported. One of the studies conducted in Wales on birch trees (Cadiz, 2002) showed changes in stomatal characters relative to their location in the mine spoil heaps of lead. More tolerant birch trees had stomata that were smaller but greater in number than in the less tolerant ones.

b. Nodulation and nitrogen fixation

Because metalliferous sites are very poor in nutrients, the use of leguminous plants to remediate heavy metal contaminated sites could be ideal (Cadiz, 2002). *Acacia mangium* and *Samanea saman* have been observed to be promising in cadmium- and lead-contaminated sites, respectively. Among agronomic crops, mungbean (Pag-asa 1) showed a potential to tolerate cadmium and lead contamination.

CONCLUSION AND RECOMMENDATION

Phytoremediation is the use of green plants to remove pollutants from the environment or render them harmless. This technology can be applied in terrestrial and aquatic environments. Plants help clean up soils contaminated with heavy and toxic metals. They are aesthetically pleasing, self-sustaining and cost-effective.

Amidst the array of tolerance mechanisms of plants to heavy metals reported, it is evident that a common universal mechanism conferring tolerance to toxic metals in plants is most unlikely. The molecular and physiological mechanisms of tolerance to heavy metals are still poorly understood, and for this reason, must still be explored.

There is a vast wealth of plants whose potential to tolerate high concentrations of heavy metals and other toxic and hazardous wastes is still untapped. In order for the phytoremediation technology to take root in our country, there is a need for an extensive survey, identification and screening of these plants. Researchers can begin with the plants that are natural colonizers of contaminated sites. The species used and identified in the vegetative rehabilitation of the Marcopper mine tailings causeway at Calancan Bay could be used as potential species to remediate similar sites. The biology of tolerance of these species, though, is yet to be studied. In addition, information on heavy metal allocation (i.e., taken up or removed by the plants, lost to seepage, etc.) is still wanting.

There is a need to select compatible plants for phytoremediation of a particular contaminated site. Since plant roots modify the immediate soil environment, there is also a need to study the interactions between the roots and the microorganisms inhabiting the rhizosphere. Other challenges involve the isolation of genes conferring tolerance to a particular heavy metal and transferring them to non-tolerant ones.

LITERATURE CITED

Alloway BJ. 1990. Soil processess and the behavior of metals. In: BJ Alloway (ed) Heavy Metals in Soils. Blackie-Glasgow pp7-28

Bautista Eva C. and RM Basada. 2002. Trial planting of rooted cuttings of selected dipterocarp species in Nabunturan, Compostela Valley Province. Ecosystems Research Digest. Vol 6 No.1 pp 14-22

Cadiz NM. 2002. Physiological and cellular markers of metal stress in some leguminous species as selection criteria for cadmium and lead tolerance (Report, UPLB Basic Research Project)

Cadiz NM, CC de Guzman and MS Davies. 1999. Cellular changes, accumulation pattern and intracellular localization of Cd, Pb and Zn in *Festuca rubra* L. cv Merlin (Red Fescue) and *Ocimum sanctum* L. (Holy Basil). Philipp Agric Sci 82: (1) 5-24

Cadiz NM. 1995. Stomatal characteristics of birch trees growing in lead mine spoil heaps. (Special Study, University of Wales College of Cardiff, UK)

Cadiz NM and Davies MS. 1996. Effects of cadmium, lead and zinc on root meristem, root hair formation, xylogenesis and development of lateral root primordial in *Ocimum sanctum* L and *Festuca rubra* L cv Merlin. In: Biology of Root Formation and Development A Altman and Y Waisel (Eds) Basic Life Sciences Vol 65. Plenum Press New York.

Cadiz NM. 1998. Tolerance strategies of plants to heavy metals: Cellular and biochemical changes in root meristems. Paper presented in the Spring Scientific Meeting of the American Society of Plant Physiologists. 16-17 April. Baltimore, Maryland, USA.

Cadiz NM, CC de Guzman and MS Davies. 1995. Root growth characteristics of *Ocimum sanctum* L. (Holy Basil) and *Festuca rubra* L. cv Merlin (Red Fescue) in response to cadmium, lead and zinc. Phillip Agr ic 78:331-342.

Casidsid, L. 2002. Trial planting of selected reforestation species in abandoned mining area at Camanlangan, New Bataan. Compostela Valley Province. Ecosystems Research Digest. Vol 6 No. 1. pp 5-12.

Davies MS. 1991. Effects of toxic concentrations of heavy metals on root growth and development. In: Plant Root Growth: An Ecological Perspective. Special Publication No. 10, British Ecological Society. D. Atkinson (ed). Blackwell Scientific Publications. Oxford. 211-227.

Diaz JF 1979. Restoration and rehabilitation of mine-out and tailings-covered area. Mod .Min. and Eng'g.1(3)18-24.

Environment Management Bureau. 1990. The Philippine Environment in the 80's.

Fellizar, FPJr, GC Saguiguit Jr, LV Castillo, LM Florece, RG Bernardo. 1997. Evaluation and Assessment of the Calancan Bay Rehabilitation Program (CBRP). SEAMEO Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Lapedes DN. 1974. Dictionary of Scientific and Technical Terms. 1st ed. McGraw-Hill, New York.

Lingkod-Tao Kalikasan. 1998. "The Destruction of Calancan Bay: The Fact." Part I.

Markert B. 1994. Plants as Biomonitors for Heavy metal pollution of the Terrestrial Environment. VCH, Weinheim.

McEldowney S, Hardmann DJ and Waite S. 1993. Treatment Technologies. In: S McEldowney J Hardmann and S Waite (eds). Pollution. Ecology and Biotreatment. Longman Singapore Publishers Pte. Ltd Singapore. 48-58.

Quarles III HD, Hanawatt RB and Odum WE. 1974. Lead in small mammals, plants and soil at varying distances from a highway. Jour Appl Ecol II. 937-949.

Street JJ, Sabey BR and Lindsay WL. 1978. Influence of pH, phosphorus, cadmium sewage sludge and incubation time on the solubility and plant uptake of cadmium. J Environ Qual. 7: 286-290.

Tomsett AB and Thurman DA. 1988. Molecular biology of metal tolerances of plants Plant Cell and Environ. 1: 383-394.

REPORT OF THE DIFFERENT GROUPS DURING THE WORKSHOP

GROUP 1 : PHYTOREMEDIATION

CHAIR : DR. MILAGROS MARTINEZ-GOSS
RAPPORTEUR : DR. MERAB A. CHAN

MEMBERS :

Dr. Charo C. Ampil (DA)
Dr. Nina M. Cadiz (UPLB)
Dr. Josefina de Jesus (DLSU)
Mr. Leopoldo de San Jose (Environmental Solution in Asia)
Dr. Pythias Espino (UPD)
Dr. Eduardo B. Principe (DENR)

1. Compelling issues and approaches

   a. Screening for plants that could sustain heavy metal and toxic wastes contamination

   b. Identify high-risk sites
      - Mining
      - Contaminated areas
      - Industrial sites

   c. Site inspection
      - Identify existing vegetation

   d. Test the plants for absorption and accumulation in the laboratory
   e. Identify the genes that are responsible for the special function
   f. Transferring identified genes to other potential plants
   g. Indoor pollution

2. Approaches:
   Laboratory screening
   Field experiment

3. Agencies to be involved:

(a) Partnering/collaboration/linkages
DENR, DOH, Academic Institutions, NGOs
- multidisciplinary

(b) Identification of funding agencies
- government - DENR
- private/industry

(c) come up with a multidisciplinary proposal that is multi-faceted.

GROUP 2 : MICROBIAL BIOREMEDIATION

CHAIR : DR. WILFREDO L. BARRAQUIO
RAPPORTEUR : DR. FRANCO G. TEVES

Members :

Dr. Nelly S. Aggangan (UPLB)
Mr. Edwin N. Camaya (UPLB)
Dr. Elizabeth C. Mabugay (ADMU)
Dr. Bernadette C. Mendoza (UPLB)
Dr. Veronica P. Migo (UPLB)
Dr. Nelson M. Pampolina (UPLB)
Dr. James Villanueva (UPD)

1. Issues: Focus on water
   - Pollutants: POPs, NO_3, heavy metals, HC

2. Approaches
   (a) Screening ⟶ Microcosm study
       ↓
       Field
   (b) Enrichment of microbial consortia
       - Focus on NO_3
         i. Aerobic
         ii. Microaerobic
         iii. Anaerobic

   (c) Study Areas:
       - Clark Air Base
       - Iligan

3. Strategy
   - High environmental impact
   - Doable
   - Use of very sensitive method of detection of degradation products

4. Agencies
   - EMB-DENR - Environmental Solutions
   - PCIERD
   - PCASTRD

5. Institutions
   - NGOs, Universities, DENR, industries

GROUP 3 : HEALTH AND SOCIETY

CHAIR	:	ACD. VERONICA F. CHAN
RAPPORTEUR	:	ACD. EVELYN MAE T. MENDOZA
Members	:	

Ms. Mila S. Antofina (PBE)
Dr. Nieva T. Librojo-Basilio (UPLB)
Dr. Leni Quirit (UPD)
Ms. Ruby Raterta (PCIERD-DOST)
Dr. Florenda Santiago (DLSU)
Ms. Rose Taguiang (PCHRD-DOST)

I. HEALTH ISSUES

- Diseases associated with pollutants
  - Cancer
  - Respiratory
  - Degenerative
  - Lifestyle related

- Occupational Related Hazards
  - Use of agricultural and household chemicals
  - Indoor pollution
  - Laboratory

II. APPROACHES

A. Institutions to be involved
- Government (DOH, DENR, DOST, DepEd, LGUs)
- NGOs (eg. PBE)
- Academe
- Industry

B. Strategies
- Networking
- Strengthening of facilities and manpower
- Focused activities (output oriented)
- Information/education campaign
- Research and development

- Monitoring / Database
- Risk Assessment
- QA

III. STRATEGY

- Focus on cancer
  - Holistic
  - Multidisciplinary

IV. FUNDING AGENCIES

- DOST
- DOH
- DENR
- ADB
- WB

V. NETWORK OF ACADEME, GOVERNMENT, INDUSTRY, NGO

Researchers with proven track record

SYNTHESIS AND CLOSING REMARKS

EMIL Q. JAVIER
Vice President
National Academy of Science and Technology

We should begin by thanking those responsible for the event. Let me recognize the IBS Committee on Toxic and Hazardous Waste Bioremediation composed of Dr. Bernadette Mendoza, Dr. Nina Cadiz, Dr. Damasa Macandog, and Mr. Edwin Camaya. We also have a Committee in NAST, of which Dr. Asuncion K. Raymundo, the youngest member, has been assigned to lead this initiative. Dr. Jose Juliano is also a member of the Committee, as well as Dr. Apolinario Nazarea who is sick, and Dr. Ruben Villareal, who is in Washington.

Thanks also to Zuellig. We appreciate that their Foundation Director himself, who happens to be in the field we are involved in, was with us; of course, the speakers, who gave us a good overview of the many possibilities of the field, and everybody who joined to make this workshop an interesting one.

Why did we come here in the first place? What was the rationale? We recognize that as economies develop and people and societies progress, there is an increasing load of pollutants in the environment. Many are natural pollutants, but many are human-generated pollutants, especially complex hydrocarbons. Whether we like it or not, they are already in the environment, and it is going to get worse before it will get better. So, the idea is for us in the scientific community to prepare and develop a national capacity to address this broad issue of how you bioremediate after there is pollution. Of course, the obvious strategy is to prevent pollution in the first place, and that can be done to some extent, but there is always the pollution that is already on the ground. And so it is our obligation in the scientific community to prepare ourselves and our successors for the task ahead. Because the challenges are going to change over time, we must prepare people to handle all these kinds of exigencies. So the strategy is to develop a national program on bioremediation, putting together the few people that we have in this area, try to generate interest among them and organize them to build a scientific network, and recruit bright young promising scientists.

This morning, my first note was to apologize to Secretary Gozun that we are so few in this room. We are so few in this meeting because there are not so many who are interested and who have the expertise to handle these kinds of problems. Although, of course, as usual, I take the positive side. I was also about to tell her that what we lack in numbers we make up for in quality.

And so the objective is to bring you together, establish a national network of like-minded scientists who can help build up your laboratories and institutions so that as the problems evolve, we will have people who can address them. Let us not lose sight of that broad perspective. The strategy is to develop a national research program on bioremediation that will gain political support and funding and resources support.

In terms of specifics, your deliberations a while ago would fall under tactics. For example, you have phytoremediation - the screening of plants tolerant to specific pollutants. What we should do is observe pioneering plants and study how to propagate them in those degraded landscapes. After all, if they are pioneering, they must be able to tolerate those heavy metals. Candidate species like cogon, talahib and *Chromolaena*, as well as other native weeds, are hardy and can be further multiplied. We tend to look at introduced species like vetiver and overlook native species. Anyway, the idea is to assess what are in those environments, look at potential plants, analyze those which perform or survive in those environments, and, in the long term, study the genes which govern accumulation of metals, sites of accumulation, and the transgenic transfer of those genes. That is for group A.

Then, there is the microbial group and the health group. Actually, there is a dilemma because the two groups are looking at the problem from their own perspective. Thus, the microbial group attacks the problem from the point of view of the external stimulus, the pollutants like nitrate. Nitrate, however, is only one of the many pollutants. The nitrate-degrading organisms, though, also consume carbon. Thus, you also break down hydrocarbons. On the other hand, the health group looks at diseases, focusing on cancer. But then, what strategy generates both political support and money at the same time?

I am therefore proposing a third approach. The problem is that bioremediation involves all kinds of pollutants and organisms. Nobody will believe us if we try to solve all of these things, and we will not be able to do so anyway. The other approach is to identify specific target sites. By identifying the target sites, you naturally confine yourself to specific pollutants most dominant in those sites. Of course, those pollutants will determine the kinds of diseases that you will look at, the kinds of social organizations and communities and the politicians whose commitment and support you will be seeking. The third approach in the proposal is that of target sites as the organizing principle, because that would naturally limit us to specific pollutants, whether in Marinduque, Clark or Iligan, since major pollutants will vary in each of these places.

Anyway, the rest of the approach or strategy involves building a political coalition. Thus, we have the DENR Secretary, as well as DOH, DOST, PCASTRD, PCIERD, the private sector, the Philippine Business for the Environment, and one or two private consulting firms dealing with business and the environment. The latter are important because it is ultimately these private groups who will do the actual work. Thus, we will be building a political coalition and identifying the institutions that can help. First, funding. The Global Environment Facility has money amounting to seven billion dollars each year, to which we can have access by submitting a Philippine proposal through DENR. Neither the DOH nor UP can do this on their own. I m sure our friends in DENR will be glad to join hands with us and help us gain access to this kind of money. As for Clark, we can get in touch with Mrs. Marie Ricciardone, the US ambassador's lady, who attended the NAST meeting. We start by building coalitions and getting in touch with institutions. It is the institutions which will implement the program. This is a national program involving all institutions which have the willingness, interest and capacity to work on bioremediation. In all three reports, we have the agencies, linkages, collaboration, and so on.

I will end at this point and once again complement the speakers and participants for joining us in this exercise. I would expect Dr. Asuncion Raymundo and some of you to be involved in further refining these ideas and preparing a draft proposal that can be brought to the attention of DENR, DOH, DA, DOST, and the private sector as well, so that there can be a framework for a national approach to handling this very important aspect of the environment. For the institutions and you individually, you can use this framework as your basis for competing for resources in your own agencies in addition to what this initiative can generate as a national program. This is part of our tactics. Each of you will be competing for your agency budgets. If you have a national framework with national approval, you have better chances of submitting those for agency or institutional funding. From a national point of view, of course, we will use this document for obtaining funding from the national government as well as from international sources.

So, with that, thank you very much and have a good day. I look forward to your coming together, at least virtually, to firm up our national research program on bioremediation.

ACKNOWLEDGMENTS

Zuellig-Pharma for co-sponsoring the Seminar Workshop on Remediation of Toxic and Hazardous Waste (THW)

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

IBS-Sub committee on Toxic and Hazardous Waste Bioremediation and Workshop Organizers: Dr. Asuncion K. Raymundo – Chair, Dr. Bernadette C. Mendoza, Dr. Nina M. Cadiz, Dr. Damasa M. Macandog and Mr. Edwin N. Camaya for their efforts in coordinating the workshop

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

Dr. Ofelia K. Bautista for the final editing of the manuscript

Scientists and representatives of academic and other institutions for their participation and contributions in the outputs of the seminar workshop