“Development of an effective phytoremediation technology for metal contaminated sites, modelling of plant-contaminant-soil interactions, and ‘phyto-mining’ of extracted metals (‘Phy-M-Mining’)”

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Abstract:

Soil contamination from industrial effluents and mining activities is a widespread issue worldwide. As soil is the buffer zone between atmosphere and groundwater, hence soil contamination poses serious threat to the groundwater and to the surrounding ecosystem. The present research program is aimed to make an indepth investigation about the remediation of contaminated sites from various metal contaminants using specific plants which have an experimental record as phytoremediation tools. Furthermore development of a model of plant-contaminants-soil interaction will be used in future remediation programs for rapid and successful remediation of polluted sites. Methods of phyto-mining will be of direct benefits to industries as maximum recovery techniques will be explored and established.

Introduction:

As an emerging technology ‘phytoremediation’ offers greater potentials to remediate contaminated sites over conventional and costly methods. Phytoremediation in its general sense means cleaning of contaminated sites with appropriate plants. Due to its clean approach to decontaminate sites it is categorized as ‘eco-friendly’ technique. Present research is aimed to explore the full potential of this method through in-depth investigation concerning specific but widespread pollutants in the environment.

As a widely used industrial chemical, soil pollution from chromium (Cr) is often reported from many industrial activities which include leather industries, textiles,

chemical synthesis, paints and others. As industrialization is a progressive trend, the environment is always at risks of facing new challenges in the coming decades. Chromium is not the only chemical, disposal of lead (Pb) and other inorganic and organic chemicals pose serious risks to groundwater and the ecosystem in general. Industries including the mentioned ones discharge huge effluents to the environment in the form of wastes or wastewater.

Although Cr is not bioavailable but plants like *Urtica dioica* ('stinging nettle') is proved to be very efficient to extract Cr from contaminated soil. Extraction of as much as 16 mg Cr/kg in the above ground parts of the plant is very promising (Shams et al. 2008). But further investigation to analyze the complete potential of this plant and not limiting its potentiality only for Cr but to include other heavy metals, and if and where possible to include organic pollution as well. As it is a fast growing plant with affinity to extract pollutants from contaminated soils, a successful scientific investigation can unearth many benefits of using this plant species for the remediation of contaminated environment.

Alongside the plants uptake of contaminants the research will focus on the 'residue biomass' – the biomass that is left after harvesting. The resulting biomass from phytoremediation can be used to extract the heavy metals - 'phyto-mining' or 'bio-mining', and the research will explore this to its utmost optimization.

Therefore, the research objectives are:

a) to find out the factors and parameters that enhance plants capacity to uptake more contaminants in its above ground parts to develop a successful phytoremediaion technology,
b) to develop a model in order to predict the interactions between plant, contaminants and soil, and the competition among the contaminants themselves through proper investigations,
c) to develop a method or technology to extract the metals from plants in order to reuse it in the industry.

Experimental Techniques and Methods:

Experimental setup will divide the study area into a number of small plots in order to facilitate various field conditions and design of the distribution of plant species. Alongside *Urtica dioica*, plants from Brassicaceae family (e.g. *Brassica napus* or *Brassica juncea*) can also be used in some plots as a 'in-between' among the nettles. Experiments will be carried out on 'single-phase' and 'multi-phase' metal compartments.

The following diagram outlines the project work:

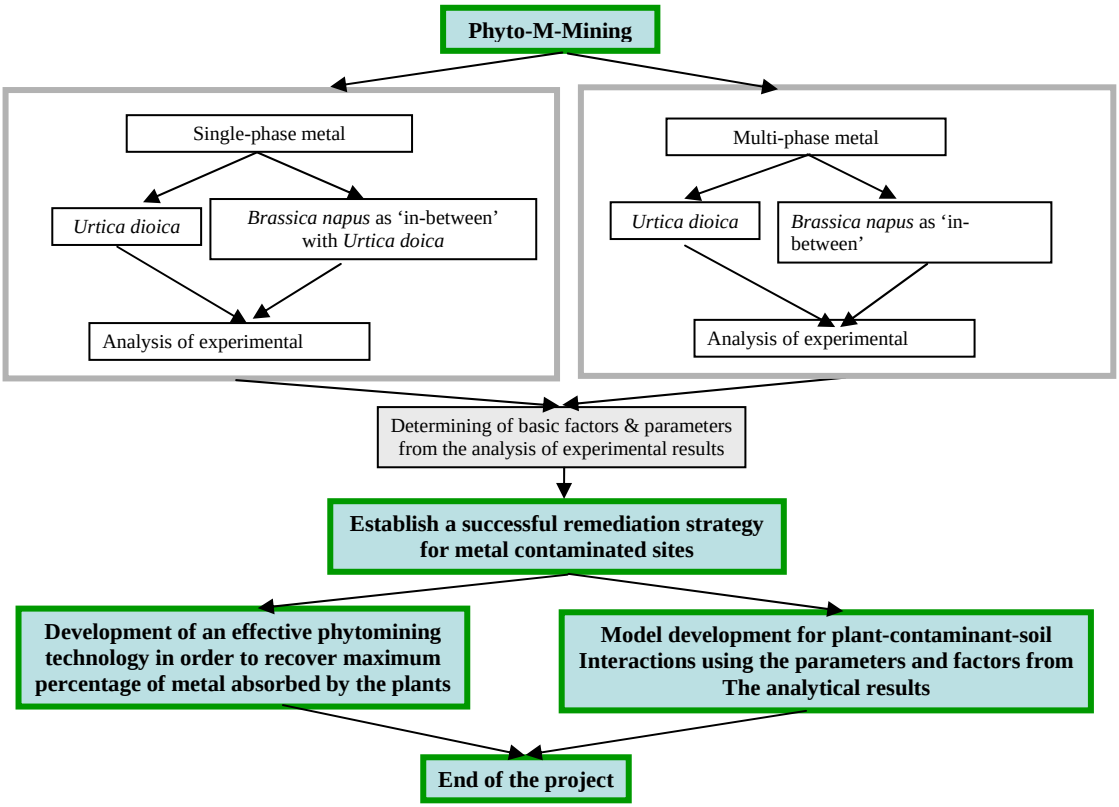

Figure 1. Flowchart of the research program

To facilitate the mass balance of contaminants on the entire system of soil and plant, proper analysis of the distribution of contaminants in every compartments of the analytical setup will be done which will yield important parameters such as **transfer**

factor and overalls **bioconcentration factor**. To investigate contaminant fate and metabolism within exposed (test) plants, root versus shoot analysis will be performed to determine such fate as accumulation and translocation.

A plant-contaminant-soil model will be developed from the studies in order to better understanding of the interactions and pathways of contaminants availability and movement in different compartments of the system. Behaviour of pollutants either in the form of competition and/or harmony towards plants uptake will be modeled to establish as criteria for predictions in the multi-phase analysis of the program. Parameters and their specific roles in the model will help assessing any remediation program for similar conditions. The model will incorporate all the essential chemical, physical and biological processes in the soil, rhizosphere and in the plant itself. These include growth rate of plants in contaminated sites, oxidative stress, absorption of metals, distribution coefficient of the contaminants (hence the availability) etc.

The research program will develop methods for successful recovery of metals from plants. Phyto-mining is very recent approach and very little work has been done in this area. Phyto-mining requires plants to accumulate substantial amount of contaminants in its above-ground parts. Plants preference for selective metals and its resistance to toxicity affect are two vital issues for phyto-mining. The research program will investigate these issues thoroughly as a successful outcome will benefit the industries economically and no wastes will be wasted rather will find its way back to the industries.

Table 1. Time table for the project ‘Phy-M-Mining’

Project Milestones	Dates
Project start	06/2008
Setup & initial operations	08/2008
Uptake study	10/2008
Uptake study	12/2008
Uptake study	02/2009
Fate analysis	06/2009
Model development & behaviour analysis	12/2009
Method development for the extraction of metals	06/2010
Environmental effects studies	10/2010
Project end & Final report	11/2010

Estimated Budget

Total Project Budget:

Table 2. Details of estimated budget for the project ‘Phy-M-Mining’

Modes of expenditures	Estimated costs in Euro (3 years)
Salary	-
Laboratory expenditures	-
Model development	-
Office expenditures	-
Others	-
Total cost	-

Results and Discussion:

The study proposed herein will facilitate the knowledge-based application of phytoremediation to the clean-up of contaminated sites. The benefits of the research will also include complete understanding to the engineering manipulation of treatment scenarios for the contaminants, evaluating the risk posed by the transfer of these contaminants between soil and plants, and evaluating the risk mitigation of phytoremediaiton processes. Furthermore the role of environmental conditions in a contaminated site, and towards its treatment processes will be assessed in order to achieve maximum benefits of phytoremediation.

Conclusion:

The results obtained and thereafter the methods developed from the research will be of direct benefit to scientific communities and remediation specialists who will use it in the real-world conditions towards achieving a greener environment.

References:

Shams K.M., Tichy G., Fischer A., Filip K., Sager M., Bashar A., Peer T. & Jozic M. (2008): Chromium contamination from tannery wastes in the soils of Hazaribagh area in Dhaka City, Bangladesh, and aspects of its phytoremediation. Geophysical Research Abstract, Vol 10, EGU2008-A-05037.