# POTENTIAL OF PHYTOREMEDIATION APPROACHES IN REGENERATION OF HAZARIBAGH BROWNFIELD AREA

**Preyanka Dey[*1], Matiur Rahman Raju[2] and Mahbuboor Rahman Choudhury[3]**

[1] *Post Graduate Student, Department of Civil Engineering, BUET, Dhaka, e-mail: pnk.buet@gmail.com*
[2] *Post Graduate Student, Department of Civil Engineering, BUET, Dhaka, e-mail: raju2010civil@gmail.com*
[3] *Assistant Professor, Department of Civil Engineering, BUET, Dhaka, e-mail: mrchoudhury@ce.buet.ac.bd*

## ABSTRACT

*Phytoremediation is an emerging, ecofriendly and viable green engineering technology that takes the advantages of using intrinsic properties of plants to redress contaminated soil, water and sediments. Soil is severely contaminated with various types of pollutants (especially by heavy metals) throughout the world and thereby throwing the living entities in a terrible health risk and disturbance to ecosystem. The soil of Hazaribagh tannery area is one of the acute heavy metal contaminated region in Dhaka city. It is high time to remediate this area from these contaminants. Conventional cleanup technologies are generally too costly to be to restore contaminated sites and are often harmful to the normal properties of soil. The incorporation of phytoremediation techniques in the contaminated soil of Hazaribagh area has been recognized as one of the most beneficial, effective and economically viable method of bio-remediation. This paper addresses phytoremediation on its characteristics, a brief overview about the soil quality of Hazaribagh area and the potential applicability of hyperaccumulator for the regeneration of Hazaribagh brownfield area.*

**Keywords:** *Phytoremediation, Heavy metals, Soil Contamination*

## 1. INTRODUCTION

The huge number of population of Dhaka city exerted pressure on land use resulting in the substantial disturbance among the environmental variables (Green, Kempa & Lackey, 1994). A major environmental concern due to the dispersal of industrial and urban wastes generated by human activities is the contamination of soil (Ghosh & Singh, 2005). Migration of people towards Dhaka city has made this situation a little bitter (Islam, 1996). As a result of it peripheral expansion of Dhaka city is phenomenal (Islam et al., 2010). Here, people use ponds, lakes, in other words shallow places as the dumping sites for industrial, commercial, urban and domestic wastes irresponsibly. At the same time, people are using the dumping areas for new construction purposes by filling it up mostly with riverbed sediment or by garbage. The riverbed sediment contains toxic chemicals and heavy metals, thereby causing significant health hazard to the local habitats.


Figure 1: Hazaribagh is very close to the river Buriganga

The Hazaribagh area of Dhaka city is located on the east-southern region of Dhaka city. It is also very close to the river Buriganga (Figure. 1). This area is mainly developed with tannery and textile industries. These industries use toxic chemicals containing lead, mercury, hexavalent chromium, cupper, zinc, nickel etc. and dump the wastes to the nearby water bodies without any prior treatment (Ahmed et al., 2010). Such metals are always toxic and non-biodegradable. It can be accumulated in the food chain and be incurred toxic effects far away from the point of generation (Tilzer & Khondker, 1993). Some of these toxic metals can replace essential metals from pigments and enzymes thereby disrupting their functions (Henry, 2000). After reaching the soil heavy metal maintain their presence there for decades and centuries, even after the removal of pollution sources. Many earlier studies show increased amount of heavy metal in the upper soil layer of urban areas (Klein, et al.,1997; Imperato et al., 2003; Chen et al., 1997; Pichtel et al., 1997). A number of studies have been undertaken to define the toxicity of Hazaribagh Brownfield area (Ahmed et al., 2010; Saha et. Al., 2011). Also, a proposal has been made to shift the tannery industries from the Hazaribagh area. But the toxicity of this area should be minimized prior to use this place for other purposes.

There are a number of soil amending techniques which are mainly grouped into two categories, ex-situ method and in-situ method. Ex-situ method refers to the excavation, detoxification and/ destruction of contaminants physically and chemically. In-situ method includes soil washing (uses particle size seperation) (Kuhlman et al., 1999; Mann 1999), covering or capping the area (prevents leaching of chemicals to ground and surface water), injection of inorganic or organic agents (changes the pH of soil and creates binding sites for toxic substances) (Guo, Zhou & Ma, 2006), vitrification (soil melted and hardened like glass like material) (Buelt & Farnsworth, 1991), electro-kinetic extraction (It is electrokinetic movement of charged particles and target metals are removed by precipitation at the electrodes) (Hicks & Tondorf, 1994) etc.

Ex-situ methods are costly to implement and are not suitable to remediate large area. The in-situ methods which are presented above are also very costly and with these, toxic substances are not removed from the site also (Oh et al., 2013). These soil remediation techniques turn the soil unsuitable for plant growth as it remove all biological activities, useful microbes as well as fauna in the process of decontamination (Burns, Rogers & McGhee, 1996).In other words they cause further damage to the already damaged environment (Alloway et al., 1991).

For this reason, phytoremediation has received attention as a relatively cheaper and eco-friendly soil remediation techniques over the decades. Phytoremediation processes rely on the characteristics of a particular group of plants, named as hyper-accumulator to take up, concentrate or metabolize contaminants to less toxic substances (Oh et al., 2013). Hyper-accumulators are typically capable of accumulating metals at levels 100 fold greater than those typically found in common plants (Salt et al., 1998; Rugh et al., 2000; Meagher et al., 2000). These species use a special mechanism of metal separation and they have a greater internal need of specific metals. These plant species render removal of heavy metals and toxic substances from the contaminated area maintaining their biological activity without disrupting the structure of soil (Baker, McGrath, Sidoli & Reeves, 1994).

So, phytoremediation has great application potential to remediate Hazaribagh heavy metal contaminated area. This paper reviews phytoremediation with its fundamental processes and characteristics, soil quality of Hazaribagh area and the potential to implement phytoremediation technology in this area by giving practical examples and test data in reference to phytoremediation.

## 2. PHYTOREMEDIATION AND ITS CHARACTERISTICS

Phytoremediation depends on the ability of plant to uptake metal. The rate and the amount of toxic substances uptake, their accumulation and degradation vary from plant to plant. Plant growth rate and biomass, their ability to tolerate and accumulate contaminants, depth of root zone etc. are the criteria to select plant for phytoremediation. These plant species also grow quickly in a wide range of environmental conditions. The possibility of apply this technology includes a broad range of contaminants including heavy metals, radionuclides, polycyclic aeromatic hydrocarbons, pesticides or insecticides, organic compounds like chlorinated solvents and surfactants etc. Fundamental processes of phytoremediation (Figure. 2) involve the following six main sub-processes:

### 2.1 Phytoextraction

Phytoextraction also refers to phytoaccumulation, involves extraction of contaminants by plant roots followed by the translocation and accumulation in the aerial parts. It is best suited for diffusely polluted areas where the pollutants concentrations are relatively low (Rulkens, Tichy & Grotenhuis, 1998). Hyperaccumulators preferentially use this technique to take up metal (0.01 % to 1 % dry weight, depending on the metal). Metals (Cd, Ni, Cu, Zn, Pb, Se,As etc), radio-nuclides and organic compounds are extracted through this process. Two basic strategies of phytoextration are : i) chelate assisted phyto-extration, in which chelating agents are added in the soil to increase the uptake and mobility of contaminants, ii)natural phytoextraction, which defines the plant's natural ability of metal uptake. *Thlaspi caerulescens, Alyssum bertolonii* etc. are the examples of hyper-accumulator plants for Cu, Ni, Zn, Cd and As respectively.

### 2.2 Phytodegradation

Phytodegradation can be called phytotransformation refers to the breakdown of contaminants into simpler molecules through the metabolic processes of plants. Different enzymes causes degradation of different compounds, such as laccases, nitrodeductases, dehalogenases causes degradation of anilines, nitroaeromatic compounds, chlorinated compounds and pesticides respectively. *Myriophyllium spicatum* and *Populas* species possesses such enzymatic systems (Schnoor et al., 1995; Rylott et al., 2008).

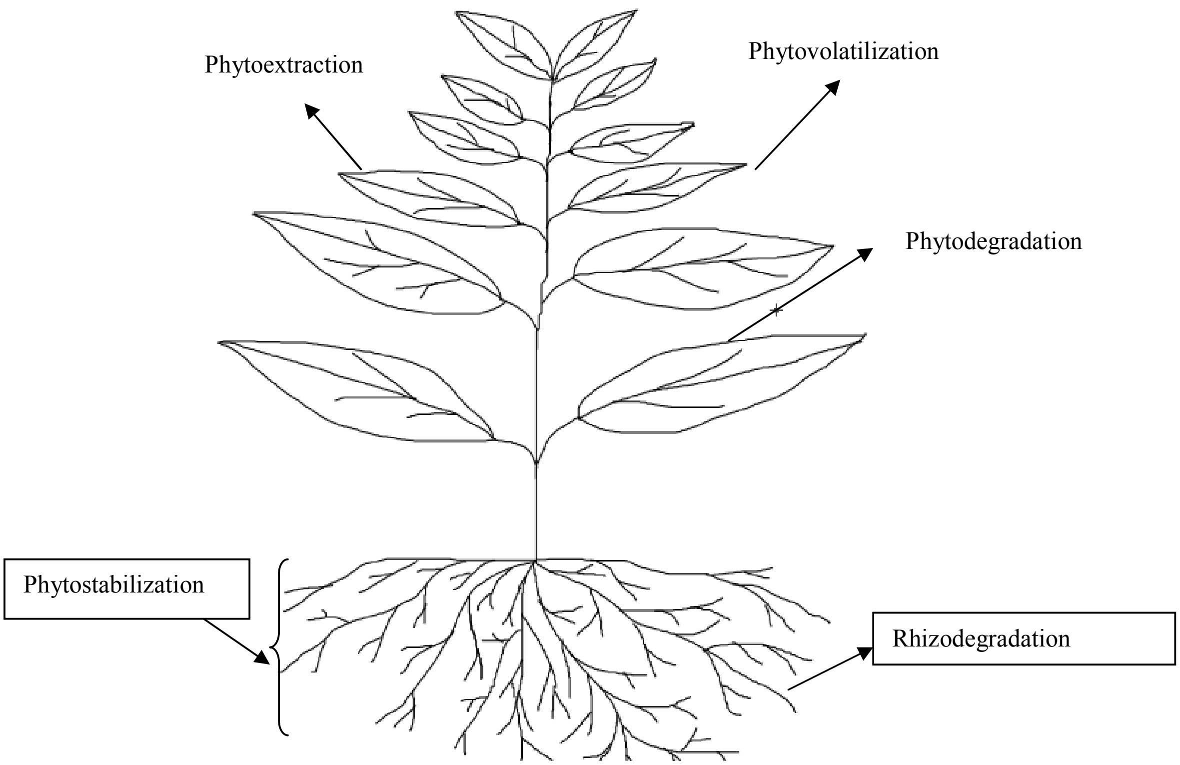


Figure 2: Processes of Phytoremediation

### 2.3 Phytovolatilization

In this process plant take up metal from soil and release the contaminants or its modified form to the atmosphere during transpiration. Some species like *Astragalus bisulcatus* and *Stanleya pinnata* for Se and *Liriodendron tulipifera* or *Brassica napus* for Hg can be mentioned (Ali et al., 2013; Pilon-Smits et al., 2000; Poschenrieder at al.,2004; Ruiz et al., 2009; Pilon-Smits etal., 2009).

### 2.4 Phytostabilization

Some plant species immobilizes contaminants in the soil and groundwater through absorption and accumulation by roots, adsorption onto roots or precipitation onto root zone. The main objective of this process is to limit the diffusion of contaminants through the soil. *Eragrostis*, *Gladiolus* and *Alyssum* etc. are name of some of the species which incur phytostabilization.

### 2.5 Rhizodegradation

Rhizodegradation, also called phyto-stimulation, refers to the breakdown of contaminants in the rhizosphere (soil surrounding the roots of plants) through microbial activity that is enhanced by the presence of plant roots. This process is much slower than phytodegradation.Some of the microorganisms like yeast, fungi, bacteria and other organisms incorporate this microbial activity. The microbial community in the rhizosphere is heterogenous due to variable spatial distribution of nutrients, however species of the genus *Pseudomonas* are the predominant organisms associated with roots (Ali et al., 2013; Crowley et al.,1997; Khan et al., 2009).

### 2.6 Phytofiltration

In this process plants with the help of their roots or other submerged organs absorb, concentrate and precipitate contaminants especially heavy metal and radioactive elements from the aqueous medium. Plants are kept in the hydroponic system, whereby effluent passes and filtered by the root zone or other organs which absorb and concentrate pollutants (Dhote et al., 2009; Ali et al., 2013).*Helianthus annus*, *Brassica juncea*, *Phragmites australis*, *Fontinalis antipyretica* are some plants that are cultivated for these purposes (Prasad et al., 2004; Dushenkov et al., 2000; Pratas et al., 2012; Favas et al., 2012).

## 3. SOIL QUALITY OF HAZARIBAGH AREA AND ITS CONSEQUENCES

A lot of industries, located in hagaribagh area has degraded the environment of this place and has made it is the worst one to suvive there. There about 200 tanneries are processing leather which accounts for most of the processed leather in Bangladesh (Saha & Ali, 2001). About 40 heavy metals and acids are used for processing raw hides (UNIDO, 2005). Tanning processes include sizing of hides,followed by weaving, bleaching, carbonizing, dyeing , finishing etc. (Correia, Stephenson & Judd, 1994). Chromium is one of the most widely used chemicals throughout the tanning processes. In addition to chromium, limestone, soda ash, NaCl, formic and sulfuric acids, sodium chlorate, cupper, zinc and cadmium containing compounds,different enzymes, waxes, lacquers, pigments etc. are used for the processing of skins and hides.

Figure 3: Water containing toxic chemicals is discharged through the drain.

A dike was constructed in the flood plain between Buriganga river and Hazaribagh after the devastating flood 1988. Wastewater from the tanneries is discharged through the open drains (Figure. 3) into the stagnant pond existing between the dike and Hazaribagh area and finally into the Buriganga river through the three outfalls. The stagnant pond area serves to retain the tannery wastewater for prolonged period of time, thereby allowing dissolved constituents (i.e. Chromium and other toxic substances) to percolate into the soil (Saha & Ali, 2001) and retain there for a long period of time. At these sites tanneries not only discharge contaminated wastewater into the rivers, but also dump a large amount of chromium-mixed solid wastes, such as skins, hides and fats onto the bank of rivers and on other other places near residential areas and villages. These leads to the contamination of water sources with Cr, Ni, Cd, Pb, Zn, Fe, Mn and Ca from the addition of tanning agents (contains Na, K, Mg, Cu etc.) (Tarik et al., 2005). A research on the Buriganga riverbed sediments has showed significant amount of heavy metals that are presented (Table 1) below (Choudhury, Islam, Ahmed & Nayar, 2015).

Table 1: Concentration of selected heavy metals in the Buriganga Riverbed Sediments close to Hazaribagh area

| **Cr (mg/kg)** | **Cu (mg/kg)** | **Pb (mg/kg)** | **Zn (mg/kg)** |
|---|---|---|---|
| 116 – 167 | 33.1 – 44.3 | 22.8 – 47 | 120 – 455 |
| Note: Heavy metal concentrations are expressed herein mg per kg of dry weight of soil | | | |

People are exposed to contaminants in various pathways. Most common hazard is the inhalation in the work site and nearby areas. Population near the tannery are often exposed to contaminated water. Water from contaminated rivers and streams are used for irrigation, swimming, bathing, washing and cleaning clothes and dishes. Riverbed sediments are used for landfill purposes. Chromium laced wastes from tanneries are often converted into poultry feed and can thus impacts on livestock and humans (Hossain, 2007). In some cases, wastes generated during tanning are added to commercially available organic fertilizers, and chromium can accumulate in the standard food crops (Grubinger et al., 1994).

## 4. LOCALLY AVAILABLE HYPERACCUMULATOR

There are a number of plants grown in and around Dhaka city, have the property to extract, concentrate or accumulate heavy metals and toxic pollutants in their root, sooth and leaves. Different hyperaccumulator have a special internal need for different specific metals, elements or compounds.Research have been shown that fern(*Pteris vittata*) is effective for removal of inorganics (As, F), Water pennyworth *(Hydrocotyle ranunculoides*) for inorganics (As, F) and metals (Pb), Vetiver grass (*Chrysopogon zizanioides*) for metals (Pb,Cd) and Sunflower (*Helianthus annuus*) for metals (Zn, Ni, Pb, Cu).Vetiver glass can grow and sustain in a heavily polluted regions compared to other species. Also Marigold (*Tagetes patula*) and Indian mustard (*Brassica juncea* ) have shown higher extraction efficiency for Cr, Cu, Pb and Zinc (Choudhury, Islam, Ahmed & Nayar, 2015). Water hyacinth *(Eichhornia crassipes)* can remove a wide variety of contaminants such as Cr, Cu, Hg, Pb, Zn, Cs, Sr, U and pesticides. Water lettuce *(Pistia stratiotes)* and Brahmi (*Bacopa monnieri)* can extracts Cu, Hg, Cr and Pb, Cd respectively. Being acquatic plant species, they (water hyacinth and water lettuce) can grow rapidly in a extensively polluted surroundings. Coconut tree (*Cocos nucifera*) and Corn (*Zea mays*) are able to accumulate radionuclides. The above plant species possess the property to remove different types of toxic substances from soil and water. These plants also grow abundantly countrywide in Bangladesh. To restore toxic substance contaminated area the inherent property of these plants can be utilized.

## 5. APPLICABILITY OF HYPERACCUMULATOR FOR HAZARIBAGH AREA

There have been some project applications of phytoremediation in America, Canada, New Zealand, Japan and in some other countries with field scales since 1980s. But, limited information is available about the project performance and time frame for the completion of projects. Full scale applications are limited only with this few number of project implications (EPA, 2005; Ji et al., 2011). The success of effective phytoremediation relies on the correct assessment of the soil quality, selection of plant species and regular monitoring and management of the restored site. Following are the some examples of field application of plant assisted bioremediation that has been used for the primary clean up of the environment.

Agricultural land in Japan was contaminated by Cd to some extent due to the irrigation with river water from mines and emission of metal smelter in the early 1970s. After that to remediate this area some cross varieties of indica-japonina with high Cd accumulation efficiency were found. Cd uptake of rice was 6 times greater than that of Indian mustard. Cd content decreased significantly in the rhizosphere after the harvesting of rice. It is estimated that by using Milyang 23 (a high Cd accumulating rice variety), remediation of a low level of Cd contaminated soil with 0.7mg $kg^{-1}$ of 0.1M HCl extractable Cd, can be finished within 3-4 years (Arao et al., 2003; Ishikawa et al., 2005).

Mining activities generate a large amount of waste rocks and tailings resulting in the loss of cultivable land, forests, grazing areas. This induces heavy metal contamination of soil. Some plant species such as *Vetiveria zizanioides, Cynodon dactylon, Typha latifolia* , *Festuca rubra* are able to grow in toxic environment (Wong, 2003). To reduce the spoils of mine from China, Vetiver grass was cultivated at South China. Results showed that Vetiver grass is highly tolerant to high temperature, drought, flood, submergence, a wide range of pH, heavy metals etc. Also Vetiver grass have more biomass and it covers more area than that of other three plants. This grass has a finely structured deep root zone effective for soil erosion control.

In New Zealand, over a 30 years period from 1966, sawdust and yard scraping from timber milling were dumped on a pile. Piles were protected in such a way so that no surface and ground water enters into the pile. Leaching resulting from the rainfall was collected in a small pond at the bottom of the pile. But overflow from the pond entered into the local stream and increased B(Born) concentration in the stream over 1.4mg/L, the New Zealand drinking water standard. To set the B concentration again allowable limit, two populous deltoids hybrid clones are cultivated at a density of 7000 trees/ha. The B concentration in the drainage water decreased gradually. After two years of successful cultivation the concentration dropped below 1.4mg/L. Total cost for the implementation of this technology including site assessment, chemical analysis and a five year maintenance plan was estimated to be NZ$ 0.2 million and cost for capping the site was NZ$ 1.2 million. So phytoremediation is both cost effective and environment friendly than capping the area (Robinson et al., 2004).

A recent research using Marigold and Indian mustard on Buriganga riverbed sediment showed satisfactory results. Buriganga river is nearby to the Hazaribagh area, whereas wastes from tannery industries and other sources are dumped in it prior to any effective treatment. Total Cr, Pb, Cu and Zn uptakes (in mg/kg of plant dry weight) by Indian mustard and Marigold plant after 12 weeks planting are presented in the following diagram (Figure. 4). Marigold showed higher uptake efficiency for Cr, Pb and Cu, while Indian mustard was found to be more efficient for Zn uptake (Choudhury, Islam, Ahmed & Nayar, 2015). Another research on the removal of arsenic using Chinese brake (*Pteris vittata* L.) showed that about 26% of the initial soil arsenic was removed by the plant after 20 weeks of transplanting. Arsenic accumulating property of the Chinise brake could be exploited on a large scale to remediate arsenic contaminated soils (Tu & Ma, 2002).

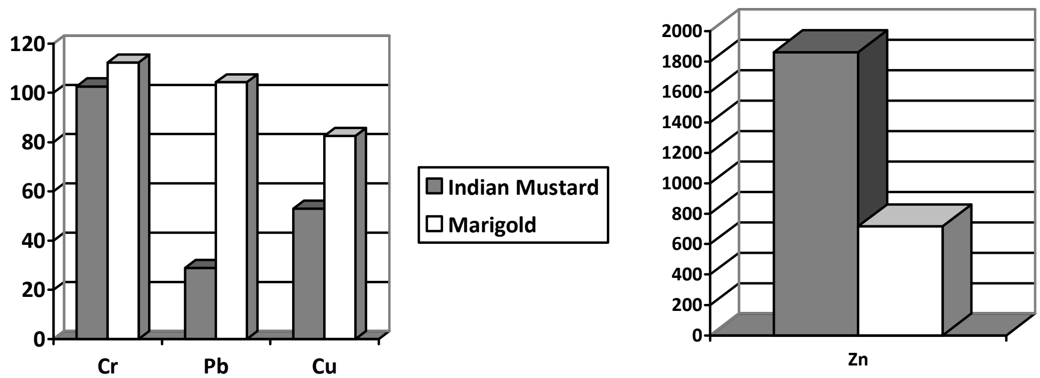


Figure 4: Heavy metal uptake by Indian Mustard and Marigold after 12 weeks planting (units of Heavy metal are in mg/kg of plant dry weight )

Above research shows that phytoremediation can be applied to regenerate Hazaribagh area. But, the concern is that people are contaminating this area by their irresponsible activities over the decades. The contaminants also entered into the deeper zone of the acquifer by this time, as in some regions of Hazaribagh, well water has shown increased amount of chromium content. The deeper strata of soil in Hazaribagh can not be remediate by applying phytoremediation at that time. But the locally available hyperaccumulator plants like sulflower, marigold, indian mustard, fern, vetiver grass can be cultivated there, to remediate the upper soil strata. This bio-remediation technology can save people and habitats of that place primarily by reducing the pollution loads from the pedosphere. Also the people who are using the Buriganga riverbed sediments for landfils, they can cultivate the hyperaccumulator in that places prior to use it for other purposes. In this way the toxicity level can be reduced there. Also the enhanced technology of phytoremediation (i.e. genetically engineered plant, chelate assisted phytoremediation, plant microbe combination etc.) can be implemented rather than simply to cultivate plants for better remediation efficiency.

## 6. CONCLUSIONS

Contaminated soil remediation using phytoremediation techniques serves the purpose of sustainable development by transfering the soil into further beneficial use, detering the spread of chemicals in the soil, water and air. Though it has proved as a cost effective measure, it is mostly suitable for the soil contaminations that is not deep enough from the soil surface. Also, the processes by which the plants extract, degrade and/ accumulate contaminants are not so far clearly undersood. Further research is essential to enhance the scope and efficiency of phytoremediation so that it can be used for the soil mixed with multi-contaminants spreaded in the deeper zone as in the case of Hazaribagh area. Complete regeneration of Hazaribagh by implying phytoremediation may not be possible at that time, as the contaminants has entered into the deeper soil strata due to the disposal of wastes unlawfully in the bare areas and water bodies over the years. But plants which has high biomass, relatively deeper root zone and effective to extract tannery wastes can be cultivated at that area to bring back the upper layer for further use and to save the local habitats from pollution gradually.

The processes of phytoremediation need to be commercialized in our country as it has been started in some other countries. Further research can be done to modify phytoremediation by applying genetically engineered high biomass plants (which have high metal uptake tendency and full growth in the polluted areas), by using chelants to increase the mobility of metal (provided that leaching of chelants should be prevented). Scope of phytoremediation can also be enhanced by implementing plant-microbes combination during cultivation so that microbes in the soil can also degrade toxic substances in addition to plants. In such a way plant cultivation period can be reduced and efficiency of phytoremediation can be increased. Modified and advanced phytoremediation techniques with enhanced metal uptake efficiency can be applied to regenerate Hazaribagh toxic substance contaminated area.

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