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Phytoremediation Technology : A review

Chatterjee Soumik[1] and Chatterjee Sabyasachi[2*]

[1,2]Department of Botany, Ramananda College, Bishnupur- 722122 Bankura, West Bengal, India

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ABSTRACT

Heavy metal pollution is one of the serious environmental problems all over the world. Heavy metals are toxic, effects on human health ,animal, bird and cause several serious diseases. Several techniques have been using for removing heavy metals from the contaminated area but these techniques have limitations such as high cost, long time, logistical problems and mechanical complexity. Phytoremediation can be used as an alternative solution for heavy metal remediation process by the plants from heavy metals contaminated area. Some heavy metals such as manganese, copper, zinc and nickel are important in very small amounts and beneficial to plants, and animals for their growth. High concentrations of all these metals have strong toxic effects and environmental threat and causes toxicity in biological systems such as animals, and plants. Heavy metals are toxic even at very low concentrations and they are not only cytotoxic in nature but also carcinogenic and mutagenic in nature.There are some conventional remediation technologies to clean contaminated areas, specifically soils contaminated with heavy metals. Phytoremediation are expensive, time consuming, and environmentally devastating. Recently, phytoremediation as a cost effective and environmentally friendly technology . It is developed in which plants are used to remediate the toxic heavy metals contaminated areas, by the help of specific metallophytes. These plants are known as hyperaccumulators for this technology. In this paper, it was reviewed sources, environmental impacts, factors affecting heavy metals bioavailability in plants and phytoremediation techniques of heavy metal contamination soil.

KEYWORDS: *Contamination, Phytoremediation, Cost effective technology*

***Corresponding author**

Sabyasachi Chatterjee[2*]

Department of Botany, Ramananda College,

Bishnupur- 722122 Bankura, West Bengal, India

Email id :- schatterjeebiotech@gmail.com

INTRODUCTION

Contamination of sediments with heavy metals is the major environmental problem all over the world. Heavy metals pollution are usually generated through industrial processes such as metals finishing industries ,metallurgy ,tannery ,battery manufacturing industries ,glass factories ,plastic industries etc release heavy metals and contaminant the soil. Quality of pedosphere, hydrosphere, atmosphere, lithosphere and biosphere are affected by Environmental pollution. Toxic metal pollution of soils is burning environmental problem, and most conventional remediation approaches do not provide acceptable solutions which are invasive and expensive .Heavy metals being a highly toxic pollutant of soils, inhibits root and shoot growth and yield production of plants, and affects nutrient uptake and homeostasis, and is frequently accumulated by agriculturally important crops which then enters the food chain with a significant potential to impair animal and human health [1] . The reduction of biomass by heavy metals toxicity could be the direct consequence of the inhibition of chlorophyll synthesis and photosynthesis. Excessive amount of heavy metals may cause decreased uptake of nutrient elements, inhibition of various enzyme activities, alterations in enzymes of the antioxidant defense system. Recently, the use of suitable plants to remediate polluted soils, has appeared as an alternative more reliable. Phytoremediation is used as a green technology and can be applied to both organic and inorganic pollutants present in soil water or in the air. Heavy metals concentrations differ between the different genotypes under the polluted soil, and the plant root system accumulated the highest heavy metals concentrations in most plant species . Phytoremediation technology uses green plants to reduce ,remove degrade or immobilize environmental toxins from soil. Metals and other pollutants, remain in the atomic form in the soil, although their speciation can change in the time together with changes in the soil conditions gradually [2]**.** Removing heavy metals from the contaminant soil is a very difficult problem now a days, because heavy metals are specific permanent pollution. In nature, heavy metals bioaccumulation causes toxicity in humans, animals, microorganisms and plants. Some heavy metals such as manganese, copper, zinc and nickel are important and require to plants, and animals, but high concentrations all of these heavy metals have strong toxic effects and harmful. Heavy metals in the environment are a source of concern because heavy metals have won potential reactivity, toxicity and mobility in humans, animals, and plants. Although individual metals exhibit specific evidence of their toxicity[3]. Different heavy metals fracture within soil require different method to separate them from the soil matrix. Accepted remediation technologies are based on biological, physical, and chemical methods, which may be used in synchronism with one another to reduce the contamination to assured and acceptable level.

HEAVY METAL POLLUTION OF SOILS:

Global population is increasing day by day and also increase industrialization and urbanization. Heavy metal release from industries and this are major reasons to contaminate the environment. Heavy metals released from industries causes the serious health problem to human life and other animals. Heavy metals also pollute the environments due to their persistence and bio-accumulative nature. Heavy metal polluted soils are treatment by Phytoextraction processes. It is the common method of phytoremediation. Bio-remediation ensures the complete removal of the pollutant [4]. Both plant and microorganisms in bioremediation increase the efficiency of remediation .In the heavy metals polluted soil bioremediation is an effective and suitable method .It is a non disturbing and effective method of soil remediation .It is a common and useful for the treatment of heavy metals polluted soil . Plants and microbes play different mechanisms for the bioremediation of polluted soil. Both plant and microorganisms combining approach to bioremediation that ensure a more efficient clean up of heavy metals from contamination soil. With the help of phytoremediation soil reduce the heavy metals toxicity , it is currently being exploited for its potential in the management of heavy metal polluted soil. Bioremediation helps reduction in the availability of heavy metals when applied in the heavy metals polluted soil and reduced absorption of the heavy metals by plant [5] .Industries are the major sources of pollution in all over the world . Based on the type of industry, various levels and quantity of pollutants can be released into the environment directly or indirectly [6]. However, the quantity of waste water discharge from industries depends on the activities and usage of water. Heavy metal pollution is a global issue, although severity and levels of heavy metals pollution differs from place to place. At least 20 metals are classified as toxic with half of them transmit into the environment in concentrations that pretend great risks to human health. The common heavy metals that have been identified in polluted water and soil includes arsenic, copper, cadmium, lead, chromium, nickel, mercury and zinc. The release of these metals without proper treatment poses a significant threat to public health because of their biomagnifications and accumulation in food chain. Many effects include reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death. Some metals, such as lead and mercury, may also cause development of autoimmunity in which a person's immune system attacks its own cells. This can lead to joint diseases such as rheumatoid arthritis, the kidney, circulatory system, and nervous system [7]. Water pollution is a major problem globally, involving the discharge of dissolved or suspended material into ground water, streams, rivers and oceans[8]. In many developing countries of the world, water pollution occurs due to incorrect management of vast amount of wastes generated by various anthropogenic activities[9]. More challenging is the unsafe

adjustment of these wastes into fresh water reservoirs used primarily for drinking and other house hold activities [10].

2. PHYTOREMEDIATION *(A promising clean up technology):*

The term "Phytoremediation" is used to describe the cleanup of heavy metals from contaminated sites by plants[11]. Phytoremediation, which makes use of plants to clean pollutants, represents a green and environment friendly tool for cleaning the heavy metal polluted soil and water. The conventional chemical and physical remediation technologies that are generally too costly and often harmful to soil characteristics. The premise of this method is to find out the hyperaccumulator of heavy metals, which has greater power to accumulate the heavy metals[12]. Heavy metals pollution affects the quality of pedosphere, hydrosphere, atmosphere, lithosphere and biosphere. Great efforts have been made in the last two decades to heavy metals pollution source and remediate the metals polluted soil. Phytoremediation is most cost effective and with fewer side effects than physical and chemical approaches which has gained increasing popularity in both academic and practical circles. More than 400 plant species have been identified to have power for soil and water remediation[13]. There are different series of phytoremediation, including phytoextraction, phytofiltration, phtostabilization, phytovolatization and phytodegradation, depending on the mechanism of remediation (figure 1). Phytoextraction involves the use of plants to remove heavy metals contaminants from soil. Phytofiltration involves the plant roots for the removal of metals from aqueous wastes. In phytostabilization, the plants root absorbs the metals pollutants from soil and keep them in the rhizosphere. Phytodegradation means the use of plants and associated microorganisms to degrade organic pollutants [14]. Rhizofiltration is the removal of pollutants from the heavy metals contaminated soil by accumulation into plant biomass. Several aquatic species have been identified and tested for the phytoremediation of heavy metals from the polluted water [15]. The roots of Indian mustard are found to be effective in the removal of cadmium, chromium, lead and zinc . The use of plants for extraction of heavy metals contaminants from the environment or for lowering of the toxicity is defined as phytoremediation [16]. The biochemical removal of heavy metals, neighborly in recent years because of its potential in environmental protection .Bioremediation is an environmental friendly and cost competitive alternative to chemical decomposition processes [17].

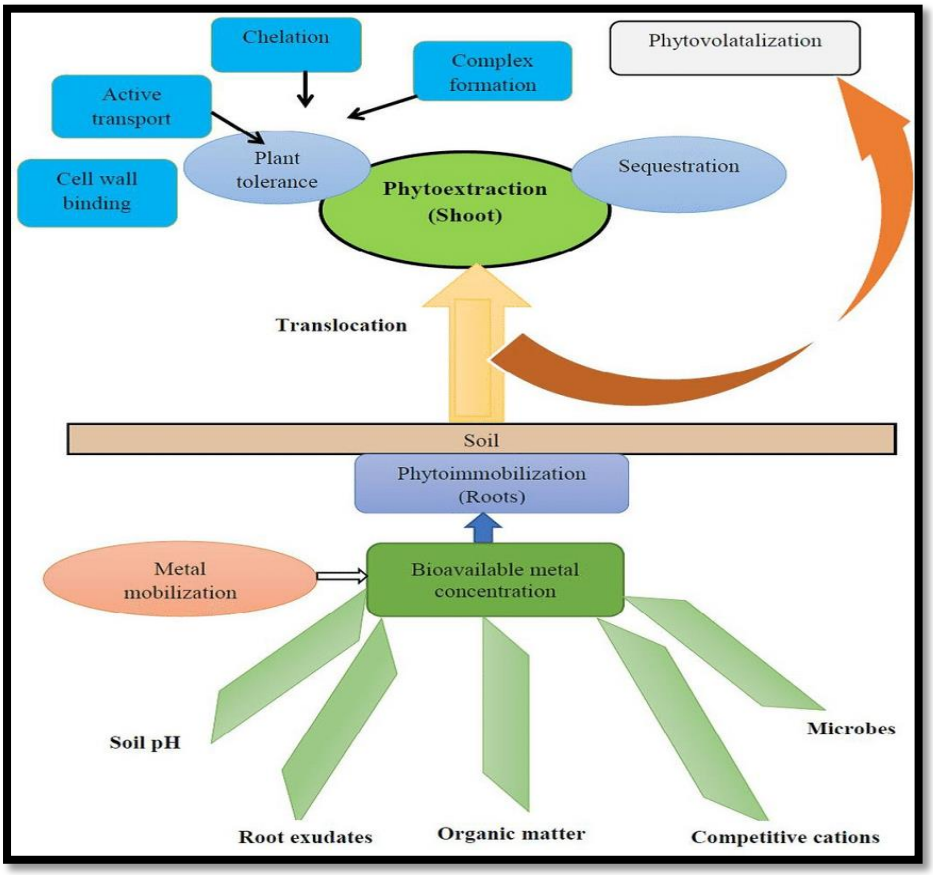

Figure1. Phytoremediation mechanism of heavy metals in soil

3. HEAVY METALS TOXICITY AND ITS MECHANISMS:

Heavy metals are not metabolized by the body and accumulate in the soft tissues because heavy metals are toxic component. Heavy metals have the ability to replace some essential minerals, for assurance Cadmium, which is presence below the zinc in the periodic table .The elements and has an atomic structure very similar to that of zinc almost fits perfectly in the zinc binding sites of critical enzymes such as RNA transferase, carboxypeptidase and alcohol dehydrogenase in the plants body [18] . Heavy metals can be poisonous for macro- and micro-organisms through direct influence on the biochemical and reducing growth, and inhibiting photosynthesis. In other words ecosystem may be exposed to chemical danger such as heavy metals (lead, chromium, arsenic, zinc, cadmium, copper, mercury and nickel) through the direct ingestion of contaminated soils, consumption of crops grown on the contaminated lands. Study indicates that entity farmers eating rice grain grown on contaminated sites throughout their lifetime are at risk from dietary exposure to heavy metals. Heavy metals produce their toxicity in organisms by forming complexes with organic compounds. These modified biological molecules lose their ability to function properly in the cells, and result in death of the affected cells. Some heavy metals may form complexes with other materials in living organisms [19]. These complexes may inactivate some important enzymes activity and certain protein

structures in cells (figure 2). heavy metals "can bind to vital cellular components, such as proteins, enzymes, and nucleic acids, and intervene with their functioning .

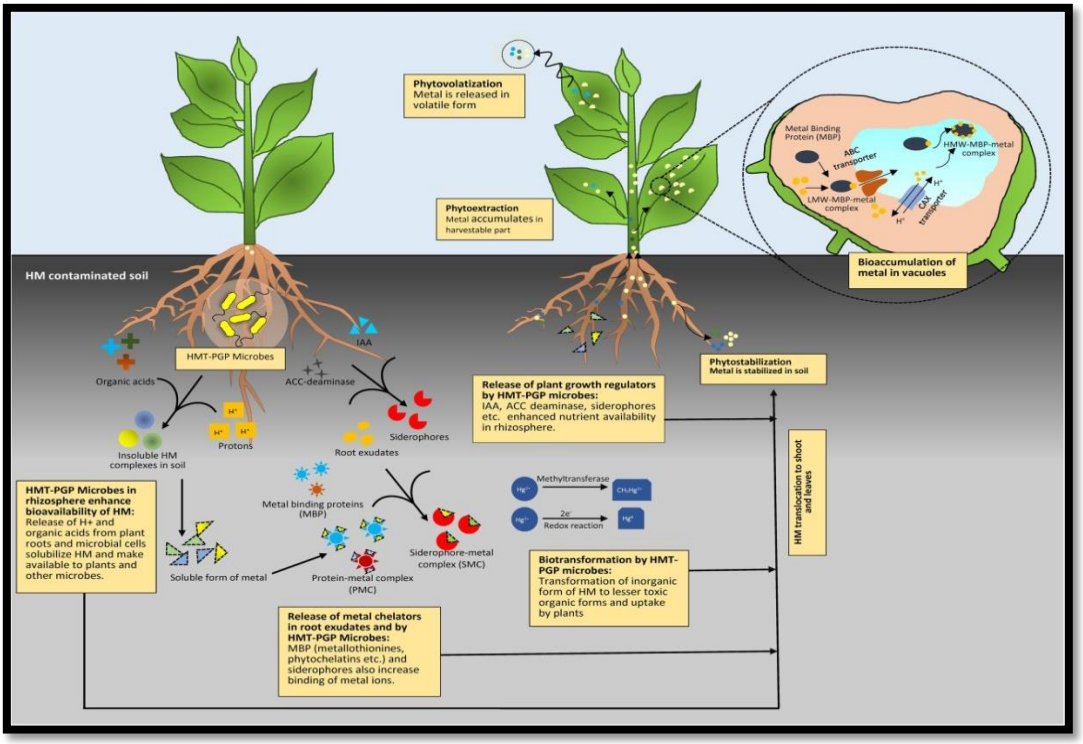

Figure 2. Heavy Metals Toxicity and its Mechanisms

4. PHYTOREMEDIATION STRATEGIES :-

Phytoremediation method include different modalities, depending on the chemical nature and properties of the contaminant area (if it is inert, volatile or subject to degradation in the plant or in the soil) and the plant characteristics (Figure 3). Thus, phytoremediation technique use six different strategies.

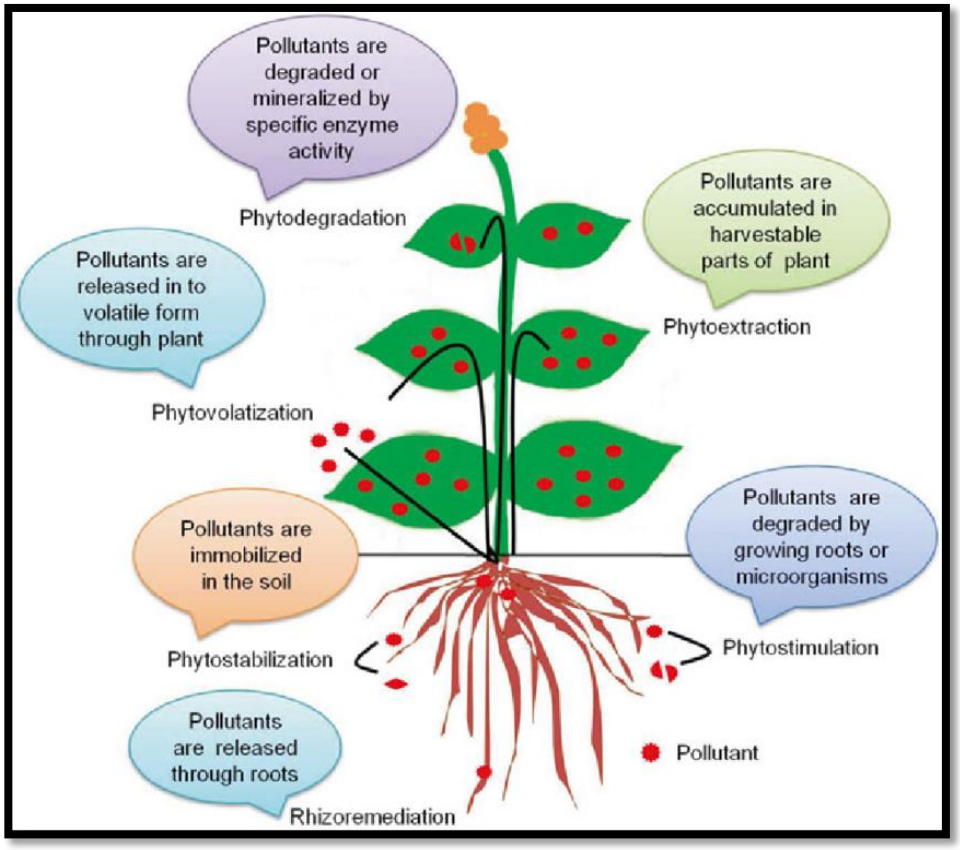

Figure 3. Schematic representation of phytoremediation strategies

a.Phytodegradation (Phytotransformation):

Organic contaminants are degraded (metabolized) or mineralized inside plant cells by specific enzymatic activity such included enzyme are nitroreductases (degradation of nitroaromatic compounds), dehalogenases (degradation of chlorinated solvents and pesticides) and laccases (degradation of anilines). Populus species are examples of plants that have these enzymatic activity .

b. Phytostabilization :

Organic or inorganic material are incorporated into the lignin of the cell wall of roots cells or into humus. Metals are precipitated as insoluble forms by direct action of root exudates of plant and subsequently trapped in the soil . The main objective is to prevent mobilization of contaminants [20]. Species of genera *Haumaniastrum*, *Eragrostis*, *Ascolepis*, *Gladiolus* and *Alyssum* are examples of plants cultivated for this Phytostabilization purpose.

c. Phytovolatilization:

This technique depend on the ability of some plants to absorb and volatilize certain heavy metals. Some element ions of the groups IIB, VA and VIA of the periodic table (specifically Hg, Se and As) are absorbed by the roots of plants and plants converted to metals from toxic forms to non-

toxic forms, and then released into the atmosphere [21]. *Astragalus bisulcatus* and *Stanleya pinnata* for Se or transgenic plants (with bacterial genes) of *Arabidopsis thaliana*, *Nicotiana tabacum*, *Liriodendron tulipifera* or *Brassica napus* for Hg can be mentioned . This technique can also be used for organic materials.

d. Phytoextraction (Phytoaccumulation, Phytosequestration):

This involves the absorption of heavy metals by roots followed by translocation and accumulation in the aerial parts of plants. It is mainly used for metals (Cd, Ni, Cu, Zn, Pb) but can also be used for other elements (Se, As) and organic materials absorption . This technique preferentially uses hyperaccumulator plants, that have the ability to store high concentrations of specific metals in their aerial parts (0.01% to 1% dry weight, depending on the metal). *Elsholtzia splendens*, *Alyssum bertolonii*, *Thlaspi caerulescens* and *Pteris vittata* are known examples of hyper-accumulator plants for Cu, Ni, Zn/Cd and As, uptake respectively .

e. Phytofiltration:

Plants absorb, concentrate or precipitate contaminants, particularly heavy metals or radioactive elements, from an aqueous medium through their root system or other submerged organs of plants. The plants are kept in a hydroponic system, whereby the effluents pass and are “filtered” by the roots (Rhizofiltration), or other organs that absorb and concentrate heavy metals [22] . *Helianthus annuus, Brassica juncea, Phragmites australis, Fontinalis antipyretica* and several species of *Salix, Populus, Lemna* and *Callitriche* plants use phytofiltration technique.

f. Rhizodegradation (Phytostimulation):

Plant roots promote the proliferation of degrading rhizosphere soil microorganisms which utilize exudates and primary ,secondary metabolites of plants as a source of carbon and energy. The application of phytostimulation is limited to organic contaminants in soil. In soil microbial community is heterogeneous due to variable spatial distribution of nutrients, however Pseudomonas are the predominant organisms associated with roots of plants. There are other strategies of plants, which are considered categories of phytoremediation of heavy metals by some authors, but actually, they are mixed techniques or variations of the above mentioned strategies of phytoremediation by plants.

g. Hydraulic barriers:

Some large trees, particularly those with deep roots (e.g., *Populus* sp.), remove heavy metals from groundwater during transpiration. Contaminants in this water are metabolized by plant enzymes, and vaporized together with water or simply sequestered in plant tissues .

h. Vegetation covers:

Herbs (usually grasses), shrubs or trees, establish on landfills or tailings, are used to minimize the infiltration of rain water and contain the spread of pollutants. The plant roots increase soil aeration thus, promoting biodegradation, evaporation and transpiration of water. The difficulty of this technique is that tailings generally inhibits the development of plant roots. However, various investigations have been under taken for developing processes of cultivation in tailings. As for example a technique in which an organic material in soil composed of sawdust, plant remains, and some NPK-fertilizers is deposited on the surface was utilized by Hungarian agronomists (Biological Reclamation Process, BRP).

I. Constructed wetlands:

Organic material, microorganisms, algae and vascular aquatic plants presence in ecosystem. A areas where the water level is at/near the surface, at least part of the year. All the components in ecosystem work together in the treatment of effluents, through the combined actions of filtration, ion exchange, adsorption and precipitation by the plants [23]. It is the oldest method of wastewater treatment and is not regarded as actual phytoremediation method, since it is based on the contributions of the entire system . Good cleaning efficiency, low cost of construction along with easy operation and maintenance are the main advantages [24]. It is widely used in the treatment of agricultural and industrial waste water, but has proved to be suitable also for treating acid mine drainages .

J. Phytodesalination:

It is a recently reported that halophytes easy to remove excess salts from saline soils. The plant such as *Suaeda sp. Sesuvium portulacastrum* remove and accumulation of NaCl, from highly saline soils, has been demonstrated. Although it has its peculiarities, this method is a modality of phytoextraction by plants.

5. METAL TOLERANCE IN PLANTS:

Heavy metals bind with the carboxyl groups of carbohydrate strongly in the cell walls leads to it diminishes transport via apoplast. An electron microscopic study root tips of plants which are

tolerant heavy metals reveal the presence of metals in the cell wall and in the cytoplasm of plant cells also. Within the plant cell the major part of metals is sequestered in the vacuole in the complexes form. Through pinocytotic vesicles, metals could be discharged in to the vacuole of leaf cell[25]. Researcher have emphasized the importance of the synthesis of heavy metal chelating compounds such as amino acids like proline to avoid metal toxicity[26]. Plants released to Pb, As and certain other heavy metals like Cd, Zn, Cu and Hg synthesize cysteine-rich low molecular weight peptide which is called phytochelatins[27]. For experiment reasons, the plant shoot metals concentration is the most important physiological parameter for evaluating metal concentration. It has been shown that heavy metals accumulation in roots portion is slightly higher than in shoots portion of plant[28] (figure 4).

6. METALLOIDS TOLERANCE IN PLANTS

Arsenic is more toxic and widely distributed in the earth's surface and present in four oxidation states: +5, +3, 0, and -3. However, the high amount of these states of Arsenic are the pentavalent and the trivalent forms. In the anion arsenate the pentavalent form occurs, in aqueous solution H2AsO4- presence [29]. In the plant cells the latter species plays several essential roles; it is a component of nucleic acids and lipids, regulates processes via phosphorylation of proteins molecule, and transports energy within the plant cells by the help of ATP. Because of its chemical similarity to phosphate, arsenate, when available inside the plant cells, can compete with and substitute for phosphate in many reactions [30]. This ability of arsenate raises questions about whether this is harmful for the cells. Previous worker has demonstrated that the main toxicity of arsenate is due to its inhibition of the energy- linked reduction of NAD+, mitochondrial respiration (citric acid cycle) and ATP synthesis in plant cell [31]. However, in normal environmental conditions, the intracellular levels of phosphate are sufficiently high that arsenate does not directly cause arsenic toxicity in plant cells.

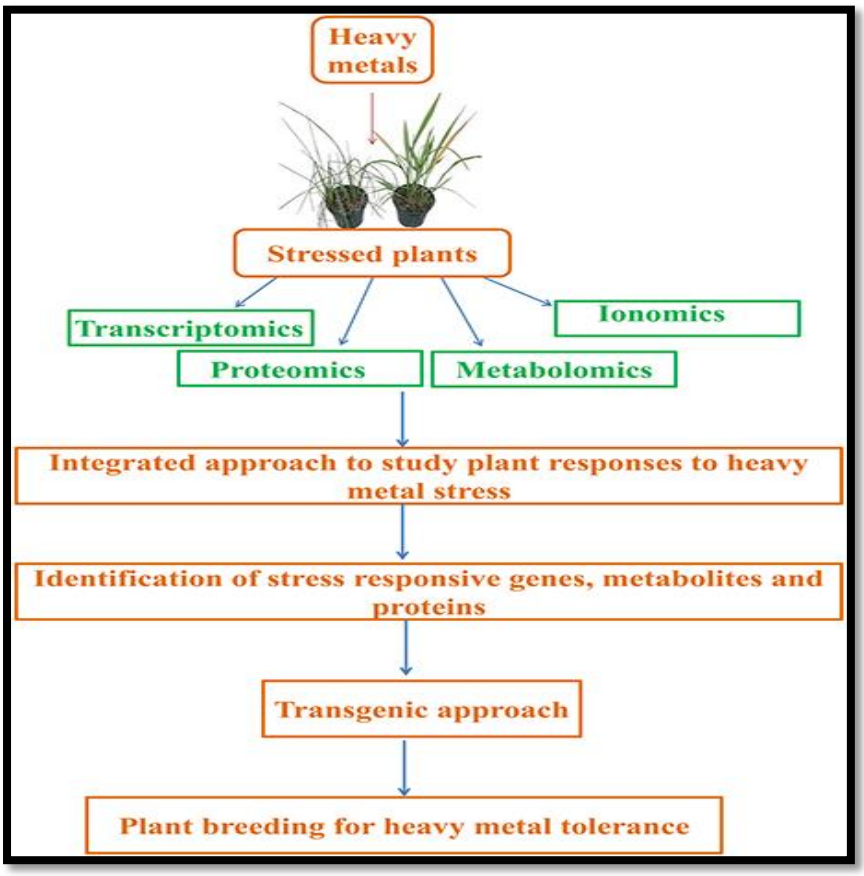

Figure 4. Metal tolerance in plants

CONCLUSION:

Accumulation of heavy metals in the environment, and pollute the environment day by day because number of industries and agricultural activities increasing day by day. Heavy metals are one of the most toxic components and contaminant the soil and water resources, as well as affect human health. Those types of metals are released into the environment through metals finishing industries ,metallurgy, tannery ,battery manufacturing industries ,glass factories ,plastic industries etc. Cd, Cu, Pb, Zn, and metalloids (e.g. As) such type of metals are considered to be environmental metallic pollutants, due to their persistence and toxicity and bio-accumulative nature and causing the serious health problem fo humans, animals, bird. Phytoremediation is a new cleanup concept that involves the use of plants to clean contaminated environments. Phytoremediation of metals from contaminant area is the most effective plant-based green technology method to remove pollutants from contaminated areas easily. This green technology can be applied by the help of plants to remediate the polluted soils without creating any affects of soil structure. Some specific plants like herbs and woody species, have been proven to have potential to absorb toxic metals from soil by phytoremediation technology.

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