

# ECO APPROACHES- VERMIREMEDIATION AND PHYTOREMEDIATION OF MERCURY AND ARSENIC TOXICITY IN SOIL

<sup>1</sup>Manish Batham, <sup>2</sup>Dr (Mrs) Jot Sharma

<sup>1</sup>Ph.D. Scholar Vijayaraje Institute of Science and Management, Turari NH-75, Jhansi Road, Gwalior-1,

<sup>2</sup>Vice Principal/Associate professor Vijayaraje Institute of Science and Management, Turari NH-75, Jhansi Road, Gwalior-1

## Abstract

Heavy metals neither are biodegradable materials nor are created. They occur naturally in earth crust and they reach in environment by the human activities (El-Kady & Abdel-Wahhab, 2018). Heavy metals are important elements for physiological and biological functions of plants, including biosynthesis of proteins, growth substances, nucleic acids, synthesis of chlorophyll and secondary metabolites (Latheef & Soundhirarajan, 2018), but the toxicity of heavy metals can reduce the plant growth and high level of the presence of these heavy metals are risk to human health (Khan et al., 2008). Present study is mainly focused on two heavy metals e.g. Mercury and Arsenic, and includes biotoxic effects on plants. Plant growth mechanism and biochemical activities are discussed along with eco approaches of remediation of heavy metals from soil are also presented in this paper e.g. vermiremediation and phytoremediation.

**Index Terms: Heavy metals, Toxicity, Vermiremediation, Phytoremediation**

## 1. Introduction

Heavy metals are important elements for physiological and biological functions of plants, including biosynthesis of proteins, growth substances, nucleic acids, synthesis of chlorophyll and secondary metabolites (Latheef & Soundhirarajan, 2018). Heavy metals neither are biodegradable materials nor are created. They occur naturally in earth crust and they reach in environment by the human activities (El-Kady & Abdel-Wahhab, 2018). Plants comprise foundation of food chain, due to uptake and biotransformation of heavy metals is a concern for human beings and other animals (Peralta-Videa et al., 2009). Heavy metals are a serious threat to soil quality due to their persistence after entering the soil (Sivakami et al., 2012). Heavy metals contain the atomic mass of greater than 20 and they are lanthanides, actinides and metalloids. They are also poisonous or toxic at low concentrations and high in atomic number or density. Heavy metals include cadmium (Cd), lead (Pb), zinc (Zn), mercury (Hg), arsenic (As), chromium (Cr), silver (Ag), copper (Cu) iron (Fe), and the platinum group elements (Duruibe et al., 2007).

### 2.1. Arsenic (As)

The word arsenic comes from the greek *arsenikon*, meaning “yellow orpiment”. It was first documented by Albertus Magnus in 1250 (Duffus, 2002). Arsenic is a chemical element with symbol **As** (atomic number 33, atomic mass 74.9) belonging to group **V**. The element itself as well as its compound is poisonous. The three most common allotropes are *metallic gray*, *non metallic yellow* and *black arsenic*, with grey being most common (Norman, 1997). Arsenic is member of nitrogen family with both metallic and non metallic (As is a semi-metallic/metalloid element) properties, and is ubiquitous in the environment (soil, water, air and also in living matters) (Tamaki & Frankenberger, 1992). It is the 20<sup>th</sup> abundant element in earth crust (Woolson, 1975), 22<sup>nd</sup> in seawater (Brown et al., 1991) and 12<sup>th</sup> in human body (Mandal & Suzuki, 2002). It has been used in various fields such as medicine, electronics, agriculture (pesticides, herbicides, insecticides, fertilizers etc.), livestock (cattle and sheep dips), and as wood

preservatives since isolation in 1250 A.D. (Mandal & Suzuki, 2002; Sharma & Sohn, 2009). It is now well recognized that consumption of arsenic, even at low levels, leads to carcinogenesis (Mandal & Suzuki, 2002).

Arsenic is rarely found as its native form because its binding affinity with other elements. In the environment, arsenic exists in four oxidation states (5,3,0 & 3) . arsenate ( $\text{As}^{\text{V}}$ ), arsenite ( $\text{As}^{\text{III}}$ ), arsenic ( $\text{As}^0$ ) and arsine ( $\text{As}^{-\text{III}}$ ) (Sharma & Sohn, 2009).  $\text{As}^{\text{V}}$  is the thermodynamically stable state for arsenic in oxic waters, while  $\text{As}^{\text{III}}$  predominates in reduced redox conditions (Cullen & Reimer, 1989).

Arsenic also occurs various organic form in the environment (Matschullat, 2000). Inorganic arsenic and its compounds, upon entering the food chain, are progressively metabolized to less toxic form of arsenic through a process of methylation (Reimer et al., 2010).

## 2.2 Arsenic Sources

The most noteworthy occurrences are located in parts of Argentina, Bangladesh, Chile, China, Hungary, India (West Bengal), Mexico, Romania, Taiwan, Vietnam and parts of USA, and SE Asia (Chakraborti et al., 2009; Flora et al., 2005; Sampson et al., 2008; Smedley & Kinniburgh, 2002; von Brömssen et al., 2007; Winkel et al., 2008). As is the constituent of Earth's crust which can enter into the environment viz. hydrosphere, lithosphere and atmosphere, through two possible source channels: anthropogenic and natural activities. Extensive use of lead arsenate and copper arsenite in pesticides called 'arsenicals' and rodenticides can be responsible for As contamination (Navarro et al., 1993; Sikdar & Banerjee, 2003).

The most abundant forms of arsenic in the environment are the inorganic  $\text{As}^{\text{V}}$  and  $\text{As}^{\text{III}}$  species, and only the organic species monomethylarsonic acid (MMAA) and dimethylarsinic acid (DMAA) can be found in detectable concentrations (Takamatsu et al., 1982; Tlustoš et al., 2002). As is one of the oldest poison in the earth's crust and biosphere and primarily associated with metals, sulphur and/or oxygen in various minerals (Banu et al., 2009). Widespread use of arsenicals as pesticides has significantly contributed to the elevation of arsenic concentrations in soil (Adriano, 2001). Redox potential (Marin et al., 1993; McGeehan & Naylor, 1994) and pH (Jain & Loeppert, 2000; Manning & Goldberg, 1997; Raven et al., 1998; Smith et al., 1999; Tyler & Olsson, 2001) are two important parameters controlling the forms and behaviour As solution; reduction of  $\text{As}^{\text{V}}$  to  $\text{As}^{\text{III}}$  result in enhanced bioavailability and toxicity to plants (Carbonell-Barrachina et al., 1999; Marin et al., 1993) and may reduce the soil productivity (Chapman, 1966; Marin et al., 1993).

Weathering of rocks converts arsenic sulfides to arsenic trioxide, which enters the arsenic cycle as dust or by dissolution in rain, rivers, or groundwater (Mandal & Suzuki, 2002). Besides the natural sources, arsenic contaminating herbicides, insecticides and rodenticides are also potential vehicles of arsenic toxicity (Gupta et al., 2005). As contamination in groundwater can also be caused due to dumping of untreated discharge and hazardous waste materials from industries (Andreae et al., 1983; Azcue & Nriagu, 1995; Chakraborti et al., 1998; Chatterjee & Banerjee, 1999; Pandey et al., 1998). It can also released in ground water through natural processes, such as volcanic ash, leaching from rock and the constituent minerals, sediment transportation and deposition (Berg et al., 2001; Bhattacharya et al., 2002; McArthur, 1999; Nicolli et al., 1989; Nriagu et al., 2007; Roychowdhury et al., 2002; Varsanyi, 1989; Zhao et al., 2010), and anthropogenic activities including coal mining and its combustion (Belkin et al., 2000; Madhavan & Subramanian, 2000; Sahu, 2002). The inorganic forms ( $\text{As}^{\text{V}}$  and  $\text{As}^{\text{III}}$ ) and the methylated forms ( $\text{MMAA}^{\text{V}}$  and  $\text{DMAA}^{\text{V}}$ ) are the main species of arsenic in natural water (Cullen & Reimer, 1989). The bulk of the total dissolved arsenic is inorganic arsenic in seawater (Peterson & Carpenter, 1983) and in fresh water (Kuhn & Sigg, 1993; Seyler & Martin, 1989).

It is also found in food, water, soil and air (Health & Services, 2000) arsenic is absorbed by all plants, but is more concentrated in leafy vegetables, rice, apple and grape juice and seafood . An additional route of exposure is through inhalation(Nwose et al., 2015).

### 2.3 Arsenic uptake in plants

Arsenic in terrestrial plants mainly occurs as inorganic arsenites and arsenates while organic arsenic species are predominant in marine organisms (Fattorini et al., 2004; Mato-Fernández et al., 2007; Šlejkovec et al., 2006). However some terrestrial plants species contain organic arsenic forms. Methylated arsenic compounds MMAA or DMAA were identified in rice, grass, bamboo shoots (Meharg & Hartley-Whitaker, 2002; Quaghebeur et al., 2003; Zhao et al., 2006). Arsenic uptake depends on arsenic concentration and speciation in soil. Based on the studies related to accumulation of arsenic in rice (Das et al., 2004; Rahman et al., 2007; Smith et al., 2008). It can be stated that about 90% of all arsenic content remains in root.

Arsenic uptake by plants is controlled by its mobility and speciation in pore water and by the exposure time of dissolved As to plant roots. The fraction of dissolved bioavailable As is a function of soil properties such as pH, Eh, draining conditions on the soil (e.g. phosphorus fertilizer addition)(Carbonell-Barrachina et al., 2009; Fendorf et al., 2004). Arsenic toxicity seems higher in sandy than clayey soils, with an estimated average toxicity threshold for crops of 40mg/kg (Sheppard, 1992; Smith et al., 1998). The distribution of As in plants generally decreases from root to stem and leaf to edible parts (Roychowdhury et al., 2005).

The use of As-rich soil in agriculture has shown accumulation of As in crops and reduced plant growth (Sheppard, 1992). An average rice yield loss of 16% has been estimated in Bengal basin rice fields containing 10 to 70 mg/kg As in topsoil (Panaullah et al., 2009), in 6 Chinese soil reduced wheat root growth was observed at 50mg/kg (Cao et al., 2009).

Arsenic uptake mechanism in terrestrial hyperaccumulating plants have been studied and reported in number of literatures (Asher & Reay, 1979; Meharg & Hartley-Whitaker, 2002; Tripathi et al., 2007; Zhang et al., 2009; Zhao et al., 2009). However, the mechanisms have been proposed for the uptake of arsenic species in aquatic macrophytes – (i) active uptake through phosphate uptake transporters, (ii) passive uptake through aquaglyceroporins, and (iii) physicochemical adsorption on root surfaces. Plants mainly uptake  $As^V$  through phosphate uptake transporters (Tripathi et al., 2007; Zhao et al., 2009), however, physicochemical adsorption on root surfaces has also been supposed to be an alternative uptake pathway for this arsenic species (Rahman et al., 2008; Robinson et al., 2006).  $As^{III}$ , DMAA and MMAA gets into the plants by passive mechanism through the aquaglyceroporin channels (Rahman et al., 2011; Zhao et al., 2009).

Previous studies on As uptake by plants have shown that As may be taken up via Pi uptake system since they have similar electron configuration and chemical properties (Ullrich-Eberius et al., 1989; Wang et al., 2002). This may due to competition between As and Pi for binding sites at the surface of root cells. In general, the phosphate/arsenate plasma membrane carriers process a much higher affinity for phosphate than arsenate (Meharg & Macnair, 1992).

Recently for improving the phytoremediation a diverse group of microorganisms (Idris et al., 2004; Zarei et al., 2010; Zarei et al., 2008) are used. The microbe-mediated processes, in which the microbial metabolites/processes in the rhizosphere affect plant metal uptake by altering the mobility and bioavailability (Aafi et al., 2012; Glick, 2010; Ma et al., 2011; Miransari, 2011; Rajkumar et al., 2010; Wenzel, 2009; Yang et al., 2012).

### 3.1 Mercury (Hg)

Mercury is naturally occurring metal that is several forms. Metallic mercury is shiny, silver-white, odourless liquid. Mercury combines with other elements, such as chlorine, sulfur, or oxygen, to form inorganic mercury compounds or salts, which are usually white powders or crystals. Mercury also combines with carbon to make organic mercury compounds (Tangahu et al., 2011b). Mercury which has the lowest melting point ( $-39^{\circ}C$ ) of all the pure metals, is only pure metal that is liquid at room temperature. However, due to its several physical and chemical advantages such as its low boiling point ( $357^{\circ}C$ ) and easy vaporization, mercury is still an important material in many industrial products (Cheng et al., 2009). As any other metal, mercury could occur in the soil in various forms. It dissolves as free ion or soluble complex and is non-specifically adsorbed by binding

mainly due to the electrostatic forces, chelated, and precipitated as sulphide, carbonate, hydroxide, and phosphate. There are three soluble forms of Hg in the soil environment (Tangahu et al., 2011a). The most reduced is Hg<sup>0</sup> metal with the other two forms being ionic of mercurous ion Hg<sup>2+</sup> and mercuric ion Hg<sup>2+</sup>, in oxidizing conditions especially at low pH. Hg<sup>+</sup> ion is not stable under environmental conditions since it dismutates into Hg<sup>0</sup> and Hg<sup>2+</sup> (Tangahu et al., 2011a). A second potential route for the conversion of mercury in the soil is methylation to methyl or dimethyl mercury by anaerobic bacteria (Colombo et al., 2014). Mercury is persistent environmental pollutant with bioaccumulation activity in fish, animals and human beings (Li et al., 2009). Mercury salts and organo-mercury compounds are among the most poisonous substance in our environment. The mechanism and extend depend strongly on the type of compound and the redox state of mercury (Barkay & Wagner-Döbler, 2005). Environmental contamination due to mercury is caused by several industries, petrochemicals, mining painting and also by agricultural sources such as fertilizer and fungicidal sprays (Rezaee et al., 2005).

### 3.2 Mercury sources

Some of the common sources of mercury found throughout the environment include but may not be limited to the household bleach, acid and caustic chemicals (e.g., battery acid, household lye, muriatic acid (hydrochloric acid), sodium hydroxide and sulfuric acid), instrumentation containing mercury (e.g. medical instruments, thermometers, barometers and monometers), dental amalgam (fillings), latex paint manufactured prior to 1990), batteries, electric lighting (fluorescent lamps, incandescent wire filaments, mercury vapor lamps, ultraviolet lamps), pesticides, pharmaceuticals (e.g., nasal sprays, cosmetics, contact lens products), household detergents and cleaners, laboratory chemicals, inks and paper coatings, lubrication oils, wiring devices and switches, and textiles. Though mercury use in many of the above items being produced now is restricted or banned, there are still some existing, older products in use (Tangahu et al., 2011b).

Mercury and its compounds are cumulative toxins and in small quantities are hazardous to human health. The major effects of mercury poisoning manifest as neurological and renal disturbances as it can easily pass the blood brain barrier and affect on the brain (Rezaee et al., 2005). Terrestrial plants are generally insensitive to the harmful effects of mercury compounds; however, mercury is known to affect photosynthesis and oxidative metabolism by interfering with electron transport in chloroplasts and mitochondria. Mercury also inhibits the activity of aquaporins and reduces plant water uptake (Pogrzeba et al., 2011).

### 3.3 Uptake of mercury on plants

Contamination of soil by mercury (Hg) is often due to the addition of this heavy metal as part of fertilizers, lime, sludges and manures as already mentioned above. The dynamic between amount of Hg that exists in the soil and its uptake by plants is not linear and depends on several variables (e.g. cation-exchange capacity, soil pH, soil aeration and the plant species). The uptake can be reduced when the soil's pH is high and/or there is an abundance of lime and salts (Patra et al., 2004; Patra & Sharma, 2000).

Another factor affecting the level of accumulation of Hg is the specific and the variety as matter of fact; at least 45 plant families include metal accumulating species (Lombi et al., 2001) most of the plant that uptake Hg tend to accumulate it on the roots (Lenka et al., 1992) and some are even able to accumulate moderate amounts in the shoots (Dushenkov et al., 1995; Kumar et al., 1995) either due to translocation or direct absorption of the vapour form. The work done by Suszcynsky and Shann (Suszcynsky & Shann, 1995) showed that plants exposed to Hg<sup>0</sup> can uptake and accumulate it in shoots, but there is no translocation to the roots.

Toxic metal ions are thought to enter plant cells by the same uptake process as micronutrients, competing with these elements for absorption. Hg, which is a class B metal (Nagajyoti et al., 2010), preferentially binds with sulphur and nitrogen ligands and is thought to enter the cell through ionic channels competing with other heavy metals like cadmium or essential metals like zinc, copper and iron (Blazka & Shaikh, 1992). However, this information is mostly based on experiments in animal cells and the authors believed that the uptake of Hg can occur via other processes which still remain unclear (Azevedo & Rodriguez, 2012).

## 4. Methods of remediation

### 4.1 Vermicomposting and Vermiremediation

Vermiremediation is the process of remediation of soil (heavy metals, soil fertility) or stopping environmental damage by the implementation of earthworms. Vermiremediation is environmental friendly process.

Vermicomposting is a bioconversion process that uses earthworms to convert biodegradable matter into vermicast (Cheng-Kim et al., 2016). Vermicomposting of agro-industrial wastes if utilized competently; represent a vast resource of plant nutrients. Various studies have shown that vermicomposting of organic waste accelerates organic matter stabilization (Frederickson et al., 2007). The role of earthworm in the breakdown of organic debris on the soil surface and in the soil turnover process was first highlighted by Darwin. Worm casts are a resource that may be used in agriculture because of their effects on nutrient dynamic and the physical structure of soil may significantly enhance plant growth and conserve better soil status (Batham et al., 2013). The most common types of earthworms used for vermicomposting are brandling worms (*Eiseniafoetida*) and red worms or red wigglers (*Lumbricusrubellus*).

Earthworms form a large portion of the invertebrate community in many soils, and play a key role in soil aeration and processing of organic matter, and are considered to be important environmental sentinel organisms. The species *Lumbricus rubellus* has been widely used in ecotoxicology and, because it is readily found in the field, it is suitable both for laboratory experiments and for studying natural populations. There have been several studies on the effects of potentially toxic elements on natural populations of *L. rubellus*, including arsenic contamination around mine sites. There is clear evidence of genetic adaptation to arsenic in earthworms from former mine sites, with population-level differences in biochemical arsenic speciation, and also biological responses to arsenic.

Sim, Cheng Kim, et al. reported that heavy metal like Copper (Cu), Manganese (Mn), Lead (Pb), Iron (Fe), Chromium (Cr), Nickel (Ni), Zinc (Zn) and Arsenic (As) decrement of heavy metal content was recorded by the implementing the vermiremediation technique on the landfill leachate contaminated soil (Sim et al., 2012).

### 4.2 Phytoremediation

Phytoremediation refers to the use of green plants and their associated micro biota for *in situ* risk reduction and/or removal of contaminants from contaminated soil, water, sediments, and air (Sharma, 2018). Phytoremediation is a reliable and environment friendly technique for cleaning up of soil. Phytoremediation of heavy metals is an emerging technology and four subsets of this technology are being developed (Pilon-Smits & Pilon, 2000; Salt et al., 1995). *Phytoextraction*, *Rhizofiltration*, *phytostabilization*, *Plant assisted bioremediation*, in which plant roots in conjunction with their rhizospheric microorganisms are used to remediate soils contaminated with organics (Anderson, 1993; Walton & Anderson, 1992). Plants that have potential benefit for heavy metals bioremediation has ability to convert inorganic mercury and arsenic to volatile forms, predominantly Dimethylselenide (DMSe), by a process called phytovolatilization (Terry et al., 2000). In addition to accumulating mercury and arsenic into the biomass, the aquatic producers are the main drivers for the volatilization of mercury and arsenic via the production of Methylated selenides including dimethylselenide (DMSe) and dimethyldiselenide (DMDS<sub>2</sub>) (Fan et al., 2002). Once the plants have successfully accumulated and stored mercury and arsenic in their tissues, the plant tissues must be harvested, removed from the contaminated site, and disposed of safely.

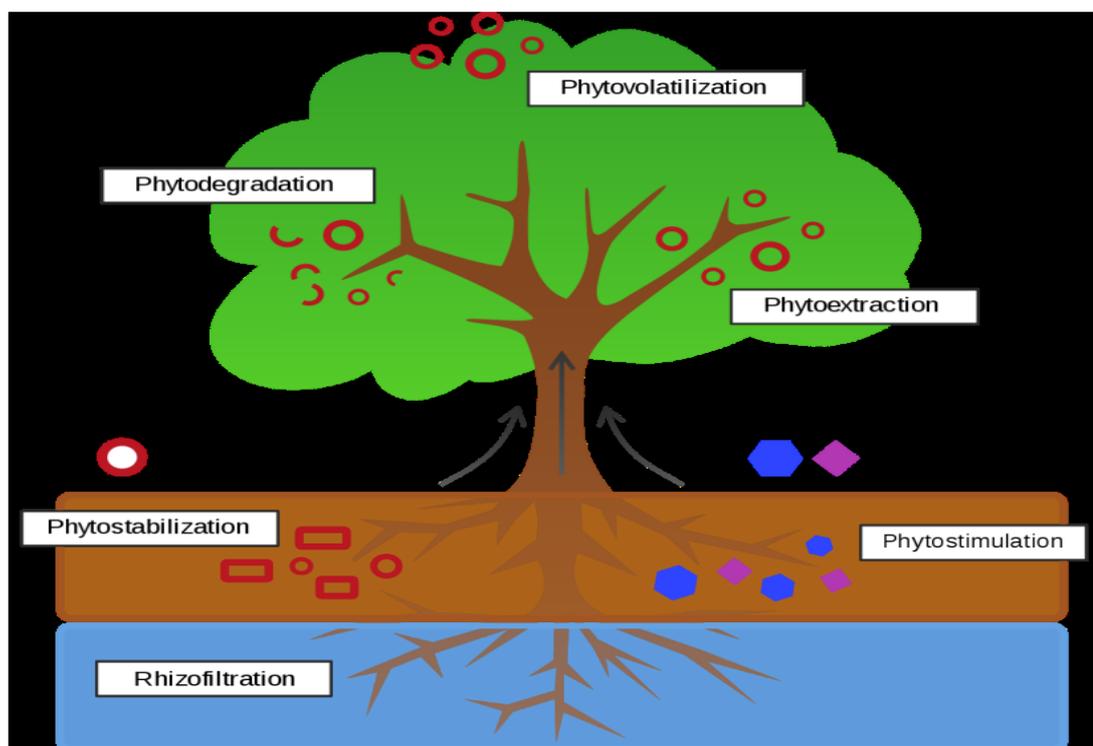


Figure: Techniques and strategies involved in Bioremediation / phytoremediation / rhizoremediation(Sharma, 2018)

#### 4.3 Phytochelatins

Chelating of metals by high affinity ligands in the cytosol are potentially a very important mechanism of heavy metal detoxification and tolerance. Potential ligands include aminoacids, organic acids and two classes of peptides the phytochelatins (PCs) and metallothionine (MT) (Clemens, 2001; Rauser, 1999). MTs and PCs were primarily identified as cadmium (Cd) binding proteins in mammalian tissues and plants respectively. Early reports of metal binding proteins in plants were generally assumed to be MTs (Cobbett, 2000).

The general structure of phytochelatins is  $\gamma$ -Glu-Cys<sub>n</sub>-Gly. Phytochelatins (PCs) consisted of solitary three amino acids such as Glutamine (Glu), Cystine (Cys) and Glycine (Gly) with the Glu, and Cys residues which are linked through a-carboxylamide bond. PCs form a family of structures with increasing repetitions of the -Glu-Cys dipeptide followed by a terminal Gly; (-Glu-Cys)<sub>n</sub>-Gly, where *n* has been reported as being as high as 11, but is generally in the range of 2 to 5 (Cobbett, 2000). PCs have been identified in a wide variety of plant species and in some microorganisms. They are structurally related to glutathione (GSH; -Glu-Cys-Gly) and were accepted to be the products of a biosynthetic pathway. In addition, a number of structural variants, for example, (-Glu-Cys)<sub>n</sub>-Ala, (-Glu-Cys)<sub>n</sub>-Ser, and (-Glu-Cys)<sub>n</sub>-Glu, have been identified in some plant species (Rauser, 1995; Rauser, 1999; Zenk, 1996).

##### 4.3.1 Synthesis of PCs

Physiological, Biochemical and genetic studies on intact plants and in *in vitro* cell culture have established that glutathione (GSH) serve as substrate for the PCs biosynthesis (Rauser, 1995; Rauser, 1999; Zenk, 1996). Cell culture studies have demonstrated that the induction of PCs in presence of Cd concur with transient decrease in GSH level. This was further deep rooted on exposure of intact plants and cell cultures to an inhibitor of GSH biosynthesis, thiamine sulfoximine (BSO), which increased sensitivity of Cd with corresponding inhibition of PC biosynthesis and this inhibition, could be reversed by addition of GSH to the growth medium. In the same way genetic studies have confirmed that GSH deficient mutants of the fission yeast and Arabidopsis which are PCs deficient are hypersensitive to Cd.

It was identified for the first time from cultured cells of *Silene cucubalis* that an enzyme activity synthesized PCs from GSH by transferring a  $\gamma$ -Glu-Cys moiety from a donor to an acceptor molecule. The enzyme mediates a bisubstrate reaction in which the thiol groups of at least one substrate are usually blocked (but not necessarily throughout the formation of heavy metal thiolates). This  $\gamma$ -Glu-Cys depeptidyl transpeptidase (EC 2.3.2.15) was named PCs syntheses. The enzyme is a 95,000 Mr tetramer with a  $K_m$  of 6.7 mM for GSH. Heavy metal activates the enzyme, which acts upon glutathione substrate to produce PCs. In vitro reactions have shown that, PCs biosynthesis continued till metal ions are chelated by either PC or metal chelators like EDTA (Loeffler et al., 1989). This provides a mechanism to auto regulate the biosynthesis of PCs where the product chelates the activating metal ion and terminates the reaction. PCs syntheses activity has been detected in tomato (Chen et al., 1997) and *Arabidopsis* (Howden et al., 1995). After the structures of PCs had been elucidated and it was found that these peptides are distributed widely in the plant kingdom, it was proposed that PCs were the functional equivalent of MTs (Grill et al., 1989). Subsequently, numerous examples of MT-like genes, and in some cases MT proteins, have been isolated from a variety of plant species and it is now apparent that plants express both of these Cys containing metal-binding ligands. Furthermore, it is likely that the two play relatively independent functions in metal detoxification and/or metabolism. However, the extent to which this is true is not yet clear and will not become apparent until a complete set of MT-deficient mutants have been identified in *Arabidopsis*. PCs have not been reported in an animal species, supporting the notion that in animals, MTs may well perform some of the functions normally contributed by PCs in plants. However, the isolation of the PCs syntheses gene from plants and the consequent identification of similar genes in animal species, described below, suggest that, at least in some animal species, both of these mechanisms contribute to metal detoxification and/or metabolism. Despite considerable and rapid progress in recent years, a lack of basic understanding of metal handling in plants is still limiting the design of phytoremediation approaches. Research should be further focused on how metal sensitive crop plants can be explored for phytoremediation. The most significant recent advances in our understanding of PCs biosynthesis and function have come from molecular genetic studies using a variety of model systems. These will continue to provide a wealth of mutants for biochemical, molecular, and physiological analysis. The isolation of PCs syntheses genes from a number of species will allow a considerably greater understanding of the mechanism of metal activation of PCs biosynthesis and the catalytic mechanism itself. There is considerable potential for the application of that understanding to optimizing the process of phyto-remediation (Sharma & Subhadra, 2010).

##### **5. Combined Application of Vermiremediation and Phytoremediation**

Use of these approaches together gives improved productivity and soil fertility. In this way dual heavy metal uptake will be done by plants and earthworms also the earthworms will improve soil fertility. Although both Vermiremediation and Phytoremediation are distinct and very effective techniques for soil management, but if used in combination these techniques can bring marvelous results. In various contaminated environments (e.g. municipal dumpsites, industrially polluted lands, agro-chemically contaminated soils etc.) where soil is already affected by various pollutants, phytoremediation provides a sustainable solution for extracting out the pollutants and cleaning up the environment (Bhat et al., 2016).

##### **6. Conclusion**

Vermiremediation is a very important and effective technique of waste management. The utilization of earthworms decreases the toxicity of substances from the waste and cleans them. It likewise gives us composts and vermiwash which are great choices of chemical fertilizers. The vermicompost generated during the process is a highly nutritious product for plants which increases the fertility of soil and also enhances microbial biomass in soil.

Phytoremediation has been seen to be an all the more ecologically well disposed "green" and low tech option in contrast to more dynamic and meddling remedial strategies. Taking everything into account, there are genuine dangers related with

phytoremediation that require evaluation and recognizable proof of administration choices preceding execution of any field based tasks.

Phytochelators (PCs) are cysteine-rich polypeptides of general structure  $[y(-\text{Glu-Cys})_2-11\text{-Gly}]$ , which assume a fundamental job in the detoxification of some substantial metals (cadmium [Cd], copper [Cu], zinc [Zn], mercury [Hg], and lead [Pb]) and metalloids (arsenic) in fungi, plants, nematodes, and other organisms.

In this way, these two methods i.e. vermiremediation and phytoremediation are best technologies for waste administration, soil fertility and enhancement and decontamination of already contaminated sites.. Additionally look into must be done to enhance and investigate these methods, as they hold the way to sustainable advancement.

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