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Impact of heavy metal contamination : An overview

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ABSTRACT

The issue of heavy metal pollution is very much concerned because of their toxicity for plant, animal and human beings and their lack of biodegradability. Excess concentrations of heavy metals have adverse effects on plant metabolic activities hence affect the food production qualitatively and quantitatively. Heavy metal when reaches human tissues through various absorption pathways such as direct ingestion, dermal contact, diet through the soil-food chain, inhalation and oral intake may seriously affect their health. Therefore, several management practices are being applied to minimize metal toxicity by attenuating the availability of metal to the plants. Some of the traditional methods are either extremely costly or they are simply applied to isolate contaminated site. The biology-based technology like use of hypermental accumulator plants occurring naturally or created by transgenic technology, in recent years draw great attention to remediate heavy metal contamination. Recently applications of nanoparticle for metal remediation are also attracting great research interest due to their exceptional adsorption and mechanical properties and unique electrical property, highly chemical stability and large specific surface area. Thus, the present review deals with different management approaches to reduce level of metal contamination in soil and finally of the food chain.

Figure : 00 References : 31 Table : 00

KEY WORDS : Heavy metal, Nanotechnology, Remediation, Toxicity.

Introduction

Environmental pollution occurs due to industrialization and extraction of natural resources in large scale and it is responsible for degradation of environmental health. Among all kinds of pollution, heavy metals make a significant contribution to the environmental pollution[17]. The metal present in soil-plant system can easily enter into food chain and also cause risk for humans, animals, plants and whole environment of our modern society[5].

Heavy metals are listed as priority pollutants by the United States Environmental Protection Agency (USEPA). There are more than 70,000 chemicals in use in the world[3]. For the level of toxicity, lead, mercury, arsenic and cadmium are ranked 1st, 2nd, 3rd and 6th respectively, in the list of US Agency for Toxic Substances and Disease Registry (ATSDR), which generally lists all hazards present in toxic waste sites on the basis of their prevalence and severity of toxicity. The problem of heavy metal pollution is emerging as a matter of concern at local, regional and global scales. In aquatic and terrestrial ecosystems, high levels of heavy metals can act as ecological toxins[16,28]. In the present scenario, anthropogenic inputs of metals exceed natural inputs.

Data of central pollution control board (CPCB 2011) show that Gujarat, Maharashtra and Andhra Pradesh contribute 80% of hazardous waste (including heavy metals) in India. Apart from industries, roadways and automobiles contribute substantially to environmental burden of heavy metals since particulate matters in traffic emissions include heavy metals like lead, cadmium and arsenic.

Application of sewage sludge in agricultural fields resulted in the accumulation of heavy metals in the soil and consequently to plants.[2,18] The concentrations of trace metals in sewage water and sludge samples from River Kubanni drainage basin in Zaria City, Nigeria were studied[1]. Groundwater can be contaminated with metals directly by infiltration of leachate from land disposal of solid wasters, liquid sewage or sewage sludge, leachate

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156

from mine tailings and other mining wastes, deep-well disposal of liquid wastes, sewage from industrial waste lagoons or from other spills and leaks from industrial metal processing facilities, (*e.g.* steel plants, plating shops, *etc.*)

Total extractable trace metals (mg kg^{-1}) in sewage sludge were 184.2, 303.4 for Ni and Cu respectively[1]. In recent years, use of energy-saving compressed fluorescent lamp (CFL) bulbs has gone up enormously. Hence, the production of CFL bulbs has increased from 19 million in 2002 to 500 million in 2010. Each bulb contains 3-12 mg of mercury. With no system to recover these bulbs and safe disposal, it may prove to be a major health hazard.

The problem of heavy metal pollution is continuously worsening due to a series of human activities, leading to an intensification of research dealing with the phytotoxicity of these contaminants and with mechanisms used by plants to counter their detrimental effects[20]. Transfer of toxic elements to human food chain is a concrete danger that has to be faced in the near future. Living organisms require varying amounts of few heavy metals. Iron, Cobalt, Copper, Manganese, Molybdenum and Zinc are required by humans in trace amounts. All metals are toxic at higher concentrations[20]. Other heavy metals such as Mercury, Plutonium, Arsenic, Cadmium and Lead are toxic metals that have no known vital or beneficial effect on organisms and their accumulation over time in the bodies of animals can cause serious illness. Heavy metals disrupt metabolic functions in human beings. Excess accumulation disrupts the function of vital organs and glands such as heart, brain, kidneys, bone, liver, *etc.* These metals displace the vital nutritional minerals from their original place and hinder their biological function. These metals can enter our body through consumption of foods, beverages, skin exposure and inhaled air. Among different heavy metals, chronic exposure to low doses of cancer-causing heavy metals may induce many types of cancer. An increased lifetime risk of lung cancer death resulted from occupational exposure to dusts and mists containing hexavalent Chromium[19]. The risk of postmenopausal breast cancer may increase due to consumption of cadmium-contaminated rice and other foods[7]. Acute and chronic exposure of Arsenic could also cause numerous human health problems. They included dermal, respiratory, Cardiovascular, gas trointestinal, hematological, hepatic, renal, neurological, developmental, reproductive, immunological, genotoxic, mutagenic and carcinogenic effects (such as liver cancer)[11].

So, there is a need of technology to clean environment up to safer limit with suitable techniques, which must be easy to handle, cost-effective and feasible. A range of technologies is available for remediation of metals-contaminated soil.

General approaches to remediation of metal contamination include isolation, immobilization, toxicity reduction, physical separation and extraction. These general approaches can be used for many types of contaminates but the specific technology selected for treatment of a metals-contaminated site will depend on form of the contamination and other site-specific characteristics.

The present review covers the whole scenario of metal contamination and its effects on plant responses. It also includes remediation technologies which can be easily applied in the metal-contaminated areas.

Metal toxicity through food chain contamination

Due to continuous industrialization and urbanization activities, heavy metal pollution becomes a major cause of environmental degradation. Different countries showed different levels of metal contamination. The South and Southeast Asian countries, like peninsular Malaysia, Vietnam, India, Thailand, Philippines, Indonesia, Bangladesh and Pakistan have taken much care regarding monitoring of the contamination of agricultural soils and crops by heavy metals.

Worker[9] has studied metal (Co, Cr, Cu, Pb and Ni) contamination of water, soils and crops at two waste-water-irrigated study sites (New Farm Extension in Mufulira and Chilumba Gardens in Kafue) in Zambia. The results indicated that heavy metals were present in the water, soil and crops at the two study sites and exceeded acceptable limits[30]. It was reported that in agricultural research centre of Giza, Egypt, waster water usage for irrigation has resulted metal accumulation in soils and plants beyond maximum permissible limits, for livestock consumption[30].

By using chelating materials

The chelating agents have a property to desorb toxic metals from soil solid phases by forming strong water-soluble complexes. After complex formation, it can be removed from the soil by plants through enhanced phytoextraction or by the help of chelant, it was applied to the soil. First, chelant can desorb metals from the soil matrix and the mobilized metals move to rhizosphere for uptake by plant roots[24]. The amounts of bioavailable metals in soil solution are mainly determined by the properties of the soil and applied chelant[12,25]. In order to reduce discharge of metal chelants into ground water and for reducing impact of chelant on soil micro-organisms, its selection, its amount and process of their application are important[1,13]. It was observed that Ethylene Diamine Tetra Acetic Acid (EDTA) is one of the most powerful and commonly used chelating agents, which forms complexes with many of metal contaminants within the natural environment[23]. It was found that application wetland plant species such as *Typha sp., Salvinia sp.* and *Eichhornia sp.* in phytoremediation of lead and copper[23].

The conventional complexing agents have some undesired features such as their persistence or slow transformation in the environment, remobilization of toxic metal ions mainly from sediments and soils as well as radionuclides from radioactive waste are of great concern, therefore, their replacement and the use of chelating agents with improved biodegradability is necessary[21]. It should be stressed that most of the aminoploycarboxylic acids (such as EDTA- ethylene diaminetetraacetic acid, IDA-iminodiacetic acid, DTPA-diethylenetriaminepenta acetic acid) are resistant to conventional biological and physicochemical methods. It was found that EDTA is more efficient than [S, S]-EDDS (ethylene- diamine disuccinic acid) in extraction of Pb and Cd, but [S, S]-EDDS is more effective in the extraction of Cu and Zn[12]. It was also found that combined application of EDTA and [S, S]-EDDS led to a higher level of efficiency (*i.e.* a synergy effect) in phytoextraction of Cu, Pb, Zn and Cd that could be obtained by the application of either chelant alone[12].

By using nanotechnology

The application of nanotechnology being mainly focused on animal science and medical research. Nanotechnology can also be applied to plant science research in order to analyze plant genomics and gene function as well as improvement of crop species[15]. The application of nanotechnology for remediation of contaminants may give promising results in the future. Nanotechnology can provide a way to purify the air and water resources by utilizing nonoparticles as a catalyst and/or sensing system[6]. The search for new and advanced materials is an important task of con-temporary research in the environmental protection. It was found that application of nanostructured materials can be used as adsorbents or catalysts to remove toxic and harmful substances from waste water and air and finally from soil[29]. In order to understand possible benefits of applying nanotechnology to agriculture, the first step should be to analyze the level of penetration and transport of nanoparticles in plants. It is established that these particles tagged to agrochemicals or to other substances should reduce injury to plant tissues and amount of chemicals released into the environment. Some contact is, however, inescapable, due to the strong interaction of plants with soil growth substrates[15]. In the field of nanotechnology, production of non-materials and products containing them are rapidly developing fields, which provides many opportunities for new innovation. For the abatement of pollution, production in the field of nanotechnology is just a beginning. It can be explored to catalyze the important changes in the field of environment. The major factor which defines capability of nanoparticles as an extremely versatile remediation tool includes their very small particle sizes (1-100 nm) in comparison to a typical bacterial cell which has a diameter of the order of 1 mm (1,000 nm). Hence nanoparticles can be transported effectively by the groundwater flow. Despite their minuscule status, nanoscale particles may hold potential to cost-effectively address, some of the challenges of site remediation[27]. Applications of nanotechnology in water treatment and purification have witnessed significant developments in recent years[14,26]. However, little progress has been made regarding application of nanoparticles to improve agricultural soil quality and to reclaim drastically disturbed lands.

The role of micro-organism is indirect as they support the growth of phytoaccumulator plants thus they help in the remediation of heavy metal[29,31]. The micro-organisms, which are closely associated with roots, have been termed plant growth promoting rhizobacteria (PGPR).

The association of plant growth-promoting bacteria with plant roots may exert beneficial effects on plant growth and nutrition by N_2 fixation, production of phytohormones and siderphores and transformation of nutrient elements[10].

By using micro organisms

This remediation strategy includes application of micro-organism. Bioremediation has been regarded as an environment-friendly, inexpensive and efficient means of environmental restoration[8]. The role of microorganisms is indirect as they support the growth of phytoaccumulator plants thus they help in the remediation of heavy metal[7]. The microorganisms, which are closely associated with roots, have been termed plants growth-promoting rhizobacteria (PGPR). Plant growth promoting rhizobacteria include a diverse group of free-living soil bacteria that can improve host plant growth and development in heavy metal contaminated soils by mitigating toxic effects of heavy metals on plants. The association of plant growth promoting and nutrition by N_2 fixation, production of phytohormones and siderophores, and transformation of nutrient elements[10].

Conclusion

Increasing public awareness of environmental pollution influences search and development of technologies that help in cleanup of contaminants such as heavy metals. Heavy metal contamination of ecosystem is a major environmental concern. In order to reduce the level of metal contamination, several remediation technologies have been implemented. These techniques include immobilization methods with the help of low cast absorbent, application of some chelating agent and biology based technique, *i.e.* phytoremediation. The Techniques at the level of molecular and nanotechnology are also used to enhance remediation properties and open up new possibilities for metal remediation technique. The aim of all the remediation technology should be linked with agricultural production, food security and scale down land tenure problems. Among all techniques, an alternative and ecofriendly remediation technology should be promoted in the developed and particularly developing countries, where heavy metal contamination is a serious problem with pace of population explosion and human developmental activities.

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