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A Review on Lead Toxicity: Harmful Effect on Plants

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Abstract

In recent years, the world population has grown rapidly, along with which there has been a growth in heavy metal toxicity due to anthropogenic activities. The toxicity of lead is more than other heavy metals, which is about 10%. The plants in which lead accumulates more, have a decrease in plant growth and photosynthesis. Humans are directly and indirectly dependent on plants. Therefore, the toxic effect of lead affects human being as well as plants. The concentration of lead in plants, plant growth and lead transfer from plants to animals, the concentration of lead in the environment is constantly increasing due to natural and anthropogenic activities, have been discussed. The use of things made of heavy metals should be banned by the government. This article discusses the accumulation of lead in plants and its toxic effects.

Keywords: Heavy metal, toxicity, human and vegetable plants.

1. Introduction

The toxicity of lead is estimated to be higher than other metals. The harmful effects of lead have been seen in humans as well as plants [1-2]. Lead has always been the enemy of humans and plants. Lead is such a metal that affects almost all the organs of humans [8]. All the functions performed by the human body are affected by lead. Lead gives rise to many diseases in humans. In view of this, countries like USA and Canada have launched many campaigns to control lead [11-13]. Still, there is no sign of stopping the use of things made from lead in the country [6]. If lead continues to be used like this, it will not be good for humans and other living beings. The main reason for the increased use of lead is that it has unique physical and chemical properties which makes it a useful metal for humans. Its beneficial use has been going on for a very long time. As a result, lead has become an environmental pollutant. Since lead is non-biodegradable, the more it is used, the more its quantity will increase in the environment. Recent research has shown that education has very dangerous effects on kidney, reproductive nervous system. Adverse effects of education have been seen in both young and old humans. Comparatively more toxic effects have been seen in young children. Its effects in humans can lead to Alzheimer's, multiple sclerosis, Parkinson's disease, muscular dystrophy, cardiovascular issues, kidney damage, anemia, reproductive etc. Toxic symptoms lead to abdominal pain, headaches, irritability and in severe cases seizures and coma [10-21].

Two or more elements combine to form a lead compound Lead combines with air and water to form many compounds such as oxides, sulphides and carbonates. Lead compounds are used as rust inhibitors. It has a low melting point and can react with both acids and bases. Lead leaks mostly from factories, petrol and other oils, mixture of metals and is emitted into the air due to burning of fossil fuels. Lead enters the plants through water, soil and air due to smoke from vehicles, which hinders plant growth, photosynthesis and other functions. Due to increasing industrialisation and urbanisation, other heavy metals get accumulated in the leaves of plants, which enter the humans and other animals through vegetables, which take the form of poisoning.

Lead is the most prominent heavy metal found in soil, which is a highly harmful metal for plants. Lead is not required in plants but small amounts of lead can cause morphological physical and biochemical problems in plants [20-26]. The concentrations of the tomato may be higher while the amount of lead in tomatoes is potentially low. Lead soil capacity can be more than 2000 years, which can cause problems of type in plants. Pollution from lead out of heavy metal is about 10%, lead is used in various types of battery manufacturing, paint, gasoline alcohol addition, petrochemical refinery etc. The pH of the soil plays an important role in maintaining the lead in the soil. Plants growing in the soil take more lead from acidic soil than basic soil, lead is being used a lot like pants, toys, traditional medicines, ceramics, the use of ceramics is continuously increasing, which has a direct effect on animals, plants and environment. It is happening that the government should implement a strong rule to control it [24-32].

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2. Review of Literature

i). Pb has been used since ancient times because Pb is a very useful heavy metal for humans, but its negative effects have also been observed, such as harmful effects of lead have been observed on plants such as it disrupts enzymatic activities in plants and causes oxidative damage. Negative effects of Pb have been observed on both chemical and physical activities in plants [21].

ii). Heavy metals are a serious problem for the environment and its solution is very important. Heavy metals occur naturally and are not very harmful for the environment, but due to their continuous use by people, lead has started to be seen as a harmful heavy metal. For example, Pb has harmful effects on seed germination, plant growth, decrease in plant biomass, decrease in biosynthesis, photosynthesis and enzymatic reactions. Metal toxicity can be easily seen on ROS. Besides this, some measures are also known to reduce metal toxicity, such as NO, H2S and plant hormones can be used. NO controls antioxidants [22].

iii). They observed that lead has harmful effects on almost all types of plants, but when 'embauba' was compared with sunflower and vetiver, they observed a decrease in the biomass of the embauba plant, a decrease in root growth and a decrease in germination, whereas no harmful effects were observed on vetiver and sunflower plants [23].

iv). They concluded that as lead concentration in Rice increases, oxidative stress in the plant increases. SOD, peroxidases and GR act as partial oxidative defense against Pb induced oxidative injury in rice [24].

v). Increasing concentration of Pb in plants causes hindrance in ATP production which has a direct negative effect on plant growth, germination of seeds, seedling development, chlorophyll, photosynthesis, inhibition of Calvin cycle enzymes and reduction in absorption by roots etc. And due to increased ROS activity, excessive production of ROS leads to liquid substitution and DNA damage [25].

3. Influences of Lead Toxicity on Plants Growth and Yield Formation

Lead reduces root growth and water absorption in plants. It decreases root stability and efficiency. It also slows down photosynthesis and respiration. Lead reduces energy production by affecting chlorophyll and enzyme activities, which directly affects plant metabolic activities. This results in nutrient imbalance (lead causes instability in calcium, magnesium, phosphorus and other nutrients), which adversely affects plant health and growth [3-15].

Lead can cause oxidative stress in plants, which can lead to deformation of plant organs and cellular structures, and lead to reduced production of fruits, flowers, and seeds in plants [35-42].

4. Uptake of Lead

The absorption of lead in plants occurs through roots from water, aqueous and atmosphere. The absorption of lead in plants occurs passively and as lead is continuously absorbed, it moves throughout the plant body through xylem vessels and lead is transferred from the plant's endodermis to the endoderm, which causes imbalance in the plant's functioning [7-21]. The uptake of lead in plants also occurs through stomata present on the outer surface of the plant and the surface of the leaves. Plants grown in areas where the atmosphere contains high levels of heavy metals in dust show reduced growth because dust and heavy metals get deposited in the stomata on the leaf surface and elsewhere [11-12]. The heavy metals reach the endodermis and bind to the cell wall and plasma membrane. The endodermal cells act as a physical barrier to lead transfer as they block the symplast and apoplast pathways and the remaining lead ions continue the transfer process through the symplast pathway alone [24-36].

5. Harmful Effect of Lead

The harmful effects of lead have been seen and heard since ancient times. The harmful effects of lead have been seen in both plants and animals. The effect of lead has been seen on enzyme activity, photosynthesis, and plant growth of plants. Chloramphenicol acetyl transferase (CAT) is oxidoreductase that decomposes H2O2 to water and molecular oxygen and it is one of the important enzymes involved in the removal of toxic peroxides. CAT activities in cuttings and seedlings significantly increased at lower lead concentrations, while at higher lead concentrations it decreased. Reduced CAT activity at higher concentrations of lead might be attributed to in activation of enzymes by ROS, decrease in assembly of its subunits. Lead has adverse effects on photosynthesis and damages chlorophyll. Oxidative stress is responsive to lead exposure. Lead has adverse effects on both young and grown plants. When seeds are germinated, if they are in contact with lead then it inhibits their germination and growth. Lead-induced seed germination inhibition has been reported in Hordeum vulgare, Elsholtzia argyi, Spartina alterniflora, Pinus halepensis, Oryza satina and Zea mays. Lead causes toxicity in the plant causing swollen stems, curled leaves and harmful effects on roots [36-42].

Lipid peroxidation-Continuous lead absorption in various plants leads to lead accumulation in plants. Lead concentration in plants increases. This leads to increased antioxidant enzyme activities and chemical reactions and increases the respiratory rate in the mitochondria of plant cells, which causes an imbalance in the electron transport chain [7-9].

Photosynthesis-Plants obtain energy as a result of photosynthesis, due to which biochemical and metabolic activities in plants are possible only through photosynthesis. Increasing lead concentration can cause toxicity in plants, affecting chlorophyll plastoquinone, etc. Along with this, the activity of C3 cycle enzymes in plants slows down to a great extent. This has a direct effect on photosynthesis, as a result of which the rate of oxidative phosphorylation capacity decreases. On increasing lead concentration in plants, the activity of xylem and phloem decreases and the leaves get affected [16-20].

Oxidative Metabolism Effected by Lead Heavy metals-Disruption of Cellular Fusions-Mitochondria is a process of oxidative which is affected by lead. Production starts decreasing and ATP production is less. ATP is the form of energy [29-31].

Increased reactive oxygen species-Increased concentration of heavy metals such as lead in a plant increases the production of ROS, which in turn increases oxidative stress, causing damage to cellular structures including lipids, proteins, and nucleic acids, leading to a variety of problems including cell destruction and metabolic disorders [61-65].

Disrupting enzyme function-The process of enzymes involved in energy production slows down when lead concentration increases, such as Krebs cycle and oxidative phosphorylation. This reduces the efficiency of energy production [3].

6. Remediation

With the increasing population, the consumption of food items, grains, fruits and vegetables is also increasing. To increase the production of vegetables, fruits and grains, people are using different types of chemicals and physical treatments due to which the soil is getting polluted and the concentration of different types of chemicals and heavy metals in the soil is constantly increasing [49-55]. Their treatment is very important, such as phytoremediation, soil amendments, soil washing, microbial remediation, physical barriers, regular monitoring and sustainable practices etc. Toxic can be reduced by using hyperaccumulator plants because such plants generally absorb lead in large quantities, such as brassica juncea. Plants can reduce the concentration of lead in the soil by absorbing Pb. And we can keep the Pb concentration constant by using organic material (such as manure, biochar). The solubility of lead can be reduced by using lime, phosphate fertilizer and zeolite [22-28].

7. Conclusion

As we know heavy metals are being used since ancient times because some heavy metals have proved to be beneficial for human beings. It has also been seen that heavy metals show harmful effects directly and indirectly on animals and plants, for example, enzymatic activities and oxidative destroy are affected adversely in plants. Many different mechanisms are involved in Pb toxicity. To understand Pb toxicity, it is important to understand the harmful effects of Pb on plants at the molecular level and knowledge of plant metabolomics, transcriptomics and genomic approaches is extremely useful.

References

1. Shabaan M, Asghar HN, Akhtar MJ, Ali Q & Ejaz M. Role of plant growth promoting rhizobacteria in the alleviation of lead toxicity to Pisum sativum L. *International Journal of Phytoremediation*. 2021; 23(8):837-845.
2. Hall JL. Cellular mechanisms for heavy metal detoxification and tolerance. J Exp Bot. 2002; 53:1-11.
3. Van Asshe F, Clijsters H. Effects of metals on enzyme activity in plant. Plant Cell Environ. 1990; 13(13):195-206.
4. Burzynski M. Activity of some enzymes involved in mtrate assimilation in cu-curmber seedlings treated with lead or cadmium. Acta Physial. Plant. 1990; 12:105-106.
5. Camargo FA, Okeke BC, Bento FM, Frankenberger WT. In-vitro reduction of hexavalent chromium by a cell-free extract of Bacillus sp. ES 29 stimulated by Cu2+. Appl. Microbial. Biotechnol. 2003; 62:569-573.
6. Ding Z, Li Y, Sun Q, Zhang H. Trace elements in soils and selected agricultural plants in the tongling mining area of China. *Int. J. Environ. Res. Public Health* 15, 202-214, 2018.
7. Kumar S, Sharma P, Misra M & Misra AN. Lead induced root and shoot growth reduction in wheat (Triticum aestivum L.) is due to increase in membrane lipid peroxidation. *Journal of Pharmacognosy and Phytochemistry*. 2018; 7(1S):2080-2083.
8. Ahmad M, Lee SS, Lim JE, Lee SE, Cho JS, Moon DH, Hashimoto Y, Ok YS. Speciation and Phyto availability of lead and antimony in a small arms range soil amended with mussel shell, cow bone and biochar: EXAFS spectroscopy and chemical extractions. Chemosphere. 2014; 95:433-441.
9. Carocci A, Catalano A, Lauria G, Sinicropi MS, Genchi G. Lead toxicity, antioxidant defense and environment. Reviews of environmental contamination and toxicology, 2016, 45-67.
10. Dursun A, Uslu G, Cuci Y, Aksu Z. Bioaccumulation of copper (II), lead (II) and Chromium (VI) by growing Aspergillus Niger. Process Biochem. 2003; 38:1647-1651.
11. Elkhatib HA. Impact of lead toxicity on germination, plant growth, yield and metal uptake in radish plants. Alexandria Sci. Exch. J. 2009; 30:309-318.
12. Gupta D, Huang H, Yang X, Razafindrabe B, Inouhe M,. The detoxification of lead in Sedum alfredii H. is not related to phytochelatins but the glutathione. J. Hazard Mater. 2010; 177:437-444.
13. Neeti K, Prakash T. Effects of heavy metal poisoning during pregnancy. *Int Res J Environ Sci Int Sci Congress Assoc* [Internet]. 2013; 2:88-92
14. Deng H, Tu Y, Wang H, Wang Z, Li Y, Chai L, Zhang W, Lin Z. Environmental behavior, human health effect, and pollution control of heavy metal (loid)s toward full life cycle processes. Eco-Environ Health. 2022; 1(4):229-243. Doi: 10.1016/j.eehl.2022.11.003.
15. Hadi F. A mini review on lead toxicity in plants. J. Biol. Life Sci. 2015; 6:91-101.
16. Harpaz-Saad S, Azoulay T, Arazi T, Ben-Yaakov E, Mett A, Shiboleth YM, Hortensteiner S, Gidoni D, Galon A, Goldschmidt EE, Eyal Y. Chlorophyllase is a rate-limiting enzyme in chlorophyll catabolism and is post transnationally regulated. Plant Cell. 2007; 19:1007-1022.
17. Zulfiqar U, Farooq M, Hussain S, Maqsood M, Hussain M, Ishfaq M, Ahmad M, Anjum MZ. Lead toxicity in plants: impacts and remediation. J Environ Manage [Internet]. 2019; 250:109557
18. Keçeci M, Usta S, Uygur V. Lead adsorption in soils and the effect of soil properties: case study from Turkey. Environ Earth Sci [Internet]. 2020; 79(18):416. doi: 10.1007/s12665-020-09156-3.
19. Jiang CY, Sheng XF, Qian M, Wang QY. Isolation and characterization of a heavy metal resistant Burkholderia sp. from heavy metal contaminated paddy field soil and its potential in promoting plant growth and heavy metal accumulation in metal-polluted soil. Chemosphere. 2008; 72:157-164.
20. Joshi PK, Swarup A, Maheshwari S, Kumar R, Singh N,. Bioremediation of heavy metals in liquid media through fungi isolated from contaminated sources. *Indian J. Microbiol.* 2011; 51:482-487.
21. Zulfiqar U, Farooq M, Hussain S, Maqsood M, Hussain M, Ishfaq M & Anjum MZ. Lead toxicity in plants: Impacts and remediation. *Journal of environmental management*. 2019; 250:109557.
22. Pourrut B, Shahid M, Dumat C, Winterton P & Pinelli E. Lead uptake, toxicity, and detoxification in plants. Reviews of environmental contamination and toxicology. 2011; 213:113-136.
23. Batista AA, Santos JA, Bomfim MR, Moreira FM, Leal EF & Conceição JND. Induced changes in the growth of four plant species due to lead toxicity. Revista Brasileira de Engenharia Agrícola e Ambiental. 2017; 21(5):327-332.
24. Verma S & Dubey RS. Lead toxicity induces lipid peroxidation and alters the activities of antioxidant

enzymes in growing rice plants. Plant science. 2003; 164(4):645-655.
25. Küpper H & Andresen E. Mechanisms of metal toxicity in plants. Metallomics. 2016; 8(3):269-285.
26. Kabata-Pendias A. Soil-plant transfer of trace elements-an environmental issue. Geoderma. 2004; 122:143-149.
27. Paquin DG, Campbell S, Li QX. Phytoremediation in subtropical Hawaii—a review of over 100 plant species. Remed J. 2004; 14:127-139
28. Pollard AJ, Reeves RD, Baker AJ. Facultative hyperaccumulation of heavy metals and metalloids. Plant Sci. 2014; 217-218:8-17
29. Raskin I, Ensley BD. Phytoremediation of toxic metals: using plants to clean up the environment. Wiley, New York, 2000, 304.
30. Salt DE, Baker AJM. Phytoremediation of metals. In: Rehm HJ, Reeds G (eds) Biotechnology: environmental processes II, vol 11b, 2nd edn. Wiley-VCH Verlag Gmbh, Weinheim, 2000, 385-397.
31. Schmidt U. Enhancing phytoextraction: the effect of chemical soil manipulation on mobility, plant accumulation, and leaching of heavy metals. *J Environ Qual*. 2003; 32(6):1939-1954
32. Whiting SN, Reeves RD, Richards D *et al*. Research priorities for conservation of metal-lophyte biodiversity and their potential for restoration and site remediation. Restor Ecol. 2004; 12:106-116
33. Wilson B, Pyatt FB. Heavy metal bioaccumulation by the important food plant, Olea europaea L. in an ancient metalliferous polluted area of Cyprus. Bull Environ Contam Toxicol. 2007; 78:390-394
34. Rajkumar M, Sandhya S, Prasad MNV, Freitas H. Perspectives of plant-associated microbes in heavy metal phytoremediation. Biotechnol Adv. 2012; 30:1562-1574
35. Rascio N, Navari-Izzo F. Heavy metal accumulating plants: how and why do they do it? and what makes them so interesting? Plant Sci. 2011; 180:169-181.
36. Xu J, Tian YS, Peng RH, Xiong AS, Zhu B, Hou XL, Yao QH. Cyanobacteria MT gene Smta enhances zinc tolerance in Arabidopsis. Mol Biol Rep. 2010; 37:1105-1110
37. Zacchini M, Pietrini F, Mugnozza GS, Iori V, Pietrosanti L, Massacci A. Metal tolerance, accumulation and translocation in poplar and willow clones treated with cadmium in hydroponics. Water Air Soil Pollut. 2009; 197:23-34
38. Zayed A, Gowthaman S, Terry N. Phytoaccumulation of trace elements by wetland plants: I. Duckweed J Environ Qual. 1998; 27:715-721
39. Collin S, Baskar A, Geevarghese DM, Ali MNVS, Bahubali P, Choudhary R, Lvov V, Tovar GI, Senatov F, Koppala S, *et al*. Bioaccumulation of lead (Pb) and its effects in plants: a review. J Hazard Mater Lett [Internet]. 2022; 3:100064. doi: 10.1016/j.hazl.2022.100064.
40. Balkhair KS, Ashraf MA. Field accumulation risks of heavy metals in soil and vegetable crop irrigated with sewage water in western region of Saudi Arabia. Saudi J Biol Sci [Internet]. 2016 ;23(1):S32-21
41. Gautam A & Dubey RS. Metal toxicity in plants: Induction of oxidative stress, antioxidative defense system, metabolic alterations and phytoremediation. Molecular physiology of abiotic stresses in plant productivity, 2018, 256-290.
42. Donald AN, Donald AN, Raphael PB, Raphael PB, Olumide OJ, Amarachukwu OF. The synopsis of environmental heavy metal pollution. *Am J Environ Sci*. 2022; 18:125-134.
43. Schalk IJ, Hannauer M, Braud A. New roles for bacterial siderophores in metal transport and tolerance. Environ Microbiol. 2011; 13:2844-2854
44. Philippot L, Raaijmakers JM, Lemanceau P, van der Putten WH. Going back to the roots: the microbial ecology of the rhizosphere. Nat Rev Microbiol. 2013; 11(11):789-799. Doi:10.1038/nrmicro3109.
45. Hasan SA, Fariduddin Q, Ali B *et al*. Cadmium: Toxicity and tolerance in plants. J Environ Biol. 2009; 30(2):165-174.
46. Weast RC. CRC Handbook of Chemistry and Physics. 64th edn. CRC Press, Baca Raton 1984.Foy CD, Chaney RL, White M. The physiology of metal toxicity in plants. *Ann Rev Plant Physiol J*. 2005; 29:511-566.
47. Kohli SK, Handa N, Bali S, Khanna K, Arora S, Sharma A & Bhardwaj R. Current scenario of Pb toxicity in plants: unraveling plethora of physiological responses. Reviews of Environmental Contamination and Toxicology. 2020; 249:153-197.
48. Burzynski M. The influence of lead and cadmium on the absorption and dis-tribution of potassium, calcium, magnesium and iron in cucumber seedlings. Acta Physiol. Plant. 1987; 9:229-238.
49. Beak KH, Chang JY, Chang YY, *et al*. Phyto-remediation of soil contaminated with cadmium and/or 2,4,6-Trinitrotoluene. *J Environ Biol.* 2006; 27:311-316.
50. Szymanski M. Molecular mechanisms of lead toxicity. Bio Technologia. *Journal of Biotechnology Computational Biology and Bio nanotechnology*. 2014; 95(2).
51. Charkiewicz AE & Back Strand JR. Lead toxicity and pollution in Poland. *International journal of environmental research and public health*. 2020; 17(12):4385.
52. Pivertz BE. Ground water issue: phytoremediation of contaminated soil and ground water at hazardous waste sites, 2001, 1-36.
53. Pollard AJ, Powell KD, Harper FA, Smith JAC. The genetic basis of metal hyperaccumulation in plants. Crit Rev Plant Sci. 2002; 21:539-566
54. Fornazier RF, Ferreira RR, Vitoria AP, *et al*. Effects of cadmium on antioxidative enzyme activities in sugarcane. Biol Plant. 2002; 45:91-97.
55. Mahaffey KR. Environmental lead toxicity: nutrition as a component of intervention. Environ Health Perspect. 1990; 89:75-78.
56. Karri SK, Saper RB, Kales SN. Lead Encephalopathy Due to Traditional Medicines. Curr Drug Saf. 2008; 3:54-59.
57. Sharma P, Dubey RS. Lead toxicity in plants. Braz J Plant Physiol. 2005; 17(1):35-52.
58. Batool Z, Yousafzai NA, Murad MS, Shahid S & Iqbal A. Lead toxicity and evaluation of oxidative stress in humans. PSM Biological Research. 2017; 2(2):79-82.
59. Mishra S, Srivastava S, Tripathi R *et al*. Lead detoxification by coontail (Ceratophyllum demersum L.) involves induction of phytochelatins and antioxidant system in response to its accumulation. Chemosphere. 2006; 65(6):1027-1039
60. Pourrut B, Shahid M, Dumat C, Winterton P, & Pinelli E. Lead uptake, toxicity, and detoxification in plants. Reviews of environmental contamination and toxicology. 2011; 213:113-136.

61. Gupta N, Singh PM, Sagar V, Pandya A, Chinnappa M, Kumar R & Bahadur A. Seed priming with ZnO and Fe3O4 nanoparticles alleviate the lead toxicity in Basella alba L. through reduced lead uptake and regulation of ROS. Plants. 2022; 11(17):2227.
62. Vassavi A, Sudha Madhavi K & Ush R. Effect of lead toxicity on the growth and antioxidant enzymes in Helianthus annuus L. seedlings. *J Pharm. Res.* 2012; 5:2395-2401.
63. White PJ & Pongrac P. Heavy-metal toxicity in plants. In Plant stress physiology. Wallingford UK: Cabi, 2017, 300-331.
64. Hossain MT, Soga K, Wakabayashi K & Hoson T. Effects of lead toxicity on growth and cell wall extensibility in rice seedlings. Bangladesh Journal of Botany. 2015; 44(2):333-336.
65. Gautam A & Dubey RS. Metal toxicity in plants: Induction of oxidative stress, antioxidative defense system, metabolic alterations and phytoremediation. Molecular physiology of abiotic stresses in plant productivity, 2018, 256-290.
66. Cozma P, Asiminicesei DM, Hlihor RM, Rosca M & Gavrilescu M. Influence of cadmium and lead ions toxicity on lettuce seeds germination: a preliminary analysis. In 2019 E-Health and Bioengineering Conference (EHB). IEEE, 2019, 1-4.
67. Kalaivanan D & Ganeshamurthy AN. Mechanisms of heavy metal toxicity in plants. Abiotic stress physiology of horticultural crops, 2016, 85-102.
68. Robinson B, Fernandez JE, Madejon P, Maranon T, Murillo JM, Green S, Clothier B. Phytoex-traction: an assessment of biogeochemical and economic viability. Plant Soil. 2003; 249:117-125
69. Rozas MA, Alkorta I, Garbisu C. Phytoextraction and phytofiltration of arsenic. Rev Environ Health. 2006; 21(1):43-56.