A Review on Effects of Heavy Metal Toxicity on Plant Growth

Srinivas J.[1], Purushotham A. V.[2], Potsangbam Kumar Singh[3]

[1]Department of Environmental Science, Manipur International University, Imphal- 795 140, Manipur, India
Corresponding Author Email: *srinivasphd2018[at]gmail.com*

[2]Department of Botany, MSN Degree College, Kakinada - 533016, Andhra Pradesh, India
Email: *potsangbamk031[at]gmail.com*

[3]Department of Botany, Manipur International University, Imphal, - 795 140, Manipur, India
Email: *dravp59[at]gmail.com*

Abstract: ***Heavy metals are elements that are naturally present in the environment. Rapid industrialization and urbanization processes has led to the incorporation of pollutants such as pesticides, petroleum products, acids and heavy metals in the natural resources like soil, water and air thus degrading not only the quality of the environment, but also affecting both plants and animals. In this review, we have summarized the adverse effect of heavy metals that alter plants, affects and growth of plants. The water / Soils pollution with heavy metals have become common across the globe due to increase in geologic and anthropogenic activities. Plants growing on these water / soils show a reduction in growth, performance, and yield. Bioremediation is an effective method of treating heavy metal polluted soils. There are few suggestions, recommendations and future prospects has recommended.***

Keywords: Contamination, Environmental Pollution, Heavy metals, Heavy metal contamination and Pollution

1. Introduction

The term “heavy metal” refers to a metal or metalloid with atomic density at least five times greater than that of water (Hawkes 1997; Tchounwou et al.2012). The common heavy metals found in environment include cadmium (Cd), lead (Pb), nickel (Ni), silver (Ag), zinc (Zn), cobalt (Co), chromium (Cr), iron (Fe), arsenic (As), and mercury (Hg). The presence of high concentration of heavy metals in water, air, and soil poses a threat to all forms of life (Oliveira and Pampulha 2006). Heavy metal toxicity imposed on plants is the most challenging problem in most countries. Removal of heavy metals from a contaminated site is known as remediation (Khan et al.2000).

2. Source of Heavy Metals

Gathering of heavy metals in biosphere may take place by both natural and human activities (Fig.1). While, weathering of rocks is the chief natural source of heavy metal contamination in environment, the anthropogenic sources include mining, smelting operations, and agricultural activities (Herawati et al.2000).

2.1 Natural Sources of Heavy Metal Contamination

2.1.1 Weathering of Rocks

Heavy metals derived from rock materials represent the “lithogenic” component. The type of parent rock is the factor which determines the concentration and composition of heavy metals formed in soil. The principal heavy metal pollutants contributed by parent rock include Co, Cr, Fe, Mn, Ni, and Zn. Weathering of igneous rocks, such as Augite, Olivine, and Hornblende, gives rise to considerable amounts of heavy elements, while sedimentary rocks contribute only a small fraction (Nagajyoti et al.2010).

2.1.2 Other Natural Sources

Apart from rocks, volcanoes, wind - blown dusts and storms, natural fires, sea sprays, and aerosols (in coastal areas) are other natural sources of heavy metals (Seaward and Richardson 1990). Geothermal sources, likewise volcanic eruptions, have raised noteworthy atmospheric toxic wastes and contaminants (Eshleman et al.1971).

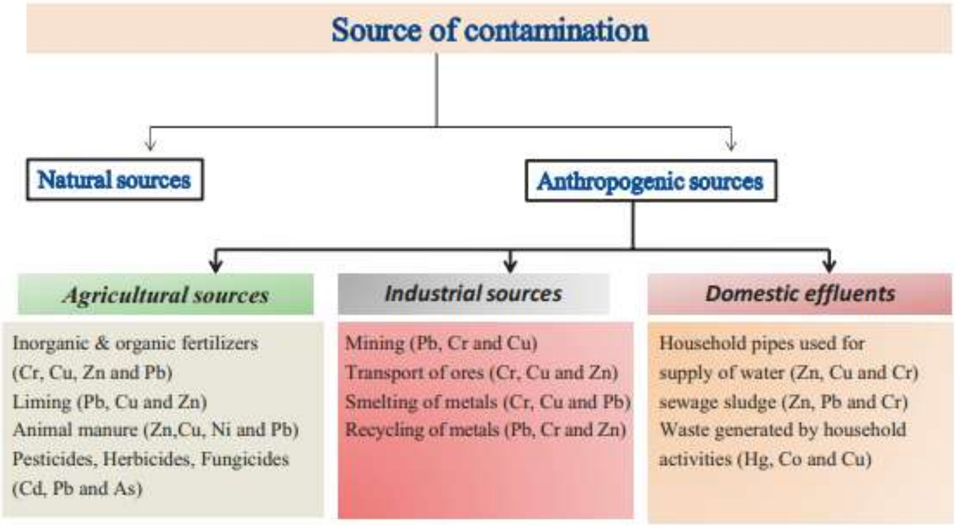

Fig. 1 Natural and anthropogenic sources of heavy metals and their composition

2.2 Anthropogenic Sources

2.2.1 Agricultural Sources

The inorganic and organic fertilizers, manure, limes, pesticides, etc., used in agriculture contain variable amounts of Cr, Cd, Ni, Zn, Pb, and other heavy metals (Nriagu 1989; Yanqun et al.2005). Similarly, most of the commonly used chemical pesticides like Bordeaux mixture and lead arsenate contain Cu, Hg, Mn, Pb, or Zn. Apart from these, use of municipal and industrial wastewater for irrigation is also a predominant source of heavy metals in soil.

2.2.2 Industrial Sources

Industrial processes like mining, smelting, and metal processing mainly generate Cr and Ni, while Vanadium (V), Titanium (Ti), and Mn are mainly derived from oil and coal - related activities (Guan et al.2018). Coal mining also liberates significant levels of As, Cd, and Fe, while gold mining increases the level of Hg in the environment (Lacerda 1997). The heavy metals are generally generated in particulate and vapor forms, which, on combining with water present in the atmosphere, form aerosols. Aerosols may be either spread by wind (dry deposition) or precipitated in rainfall (wet deposition), and cause contamination of soil and water bodies (Nagajyoti et al.2010). Also, coal and petroleum combustion and nuclear power stations give rise to heavy metals such as Se, Cd, B, Cu, Cs, Zn, and Ni to the atmosphere (Verkleji 1993). Processing of plastics, microelectronics, wood preservation, textiles and paper processing also cause heavy metal toxicity to the environment (Tchounwou et al.2012).

2.2.3 Domestic Effluents

Domestic effluents constitute the major source of heavy metal contamination in water bodies. Domestic effluents may include untreated wastewater substances and passed through the filters in biological treatment plants and waste substances are passed through sewage outfalls. Most of the widely used enzymatic detergents contain trace amounts of elements like Fe, Cr, Mn, Zn, Co, Sr, and B, thereby contributing toward heavy metal pollution (Angino et al.1970).

3. Impacts of Heavy Metal Toxicity on Plants

While, in aquatic systems, complete plant body is accessible to heavy metals and ions, terrestrial plants uptake heavy metals from the soil mainly through their roots. The uptake process is facilitated by some transport proteins, chelating agents produced in the rhizosphere, and plant - induced pH changes (Tangahu et al.2011). Other means of entry of heavy metals are stomata, lenticels, wounds, etc. (Shahid et al.2017). Heavy metals are also absorbed directly through the leaves because of particles accumulated on the foliar surfaces of leaves. Heavy metals basically cause formation of reactive oxygen species (ROS) and free radicals that lead to uncontrolled oxidation and radical chain reactions, ultimately damaging the cellular biomolecules like nucleic acids, lipids, and proteins (Phaniendra et al.2015). Plants, being primary producers, form the base of ecological pyramid; thus, the heavy metals entering the plant body make their way through successive trophic levels of the food chain. This problem gets exacerbated for the heavy metals that are bio - accumulative, that is, they are neither degraded in the environment nor easily metabolized by plants. In fact, some of the heavy metal - tolerant plant species like B. napus, B. Juncea have intrinsic ability to accumulate heavy metals in their body, thereby, threatening the contamination of food webs (Gall et al.2015; Mourato et al.2015).

3.1 Heavy Metals That Function as Micronutrients

Some heavy metals, like Cu, Fe, Mn, Mo, and Zn, function as micronutrients; that is, these are required in small quantities (less than 1 pound per acre) for important physiological functions of plants (Misra and Mani 1991). The optimum concentration of these heavy metals and their role (s) in plant development have been mentioned in Table 1. Just as lack of these nutrients results in deficiency symptoms, their elevated levels in soil also lead to toxicity effects, which have been described below.

Table 1 Range and functional roles of a few environmentally important heavy metals in plants

Elements	Land plants (μg/g dry wt)	Roles in plants
Fe	140	Component of hemoglobin, myoglobin, and cytochromes
Cu	4.15	Required for photosynthesis, acts as cofactor of superoxide dismutase, ascorbate oxidase
Zn	8–100	Main player of replication and transcription, cofactor of carbonic anhydrase, alcohol dehydrogenase
Mn	15–100	Required for photosynthesis during splitting of water, cofactor of malic dehydrogenase, oxalosuccinic dehydrogenase
Co	0.05–0.5	Found in the form of vitamin B_{12}
Ni	1	Fixes nitrogen in legumes, main component of urease enzyme

3.1.1 Iron

Iron is an important constituent of several plant proteins and enzymes like leghemoglobin, cytochromes, ferrodoxin, catalase, peroxidase, aconitase, and superoxide dismutase (Marschner 1995). However, elevated levels of iron cause production of ROS, that is, free radicals, which alter membrane permeability and damage membrane structure (De Dorlodot et al.2005).

3.1.2 Copper

Copper (Cu) is a vital co - factor for plastocyanin and cytochrome oxidase, which are involved in key physiological processes of plants like photosynthesis and respiration. However, just like other micronutrients, excessive amount of Cu has been reported to adversely affect plant growth in Brassica juncea (Singh and Tewari 2003), Solanum melongena (Neelima and Reddy 2002), Alyssum montanum (Ouzounidou 1994), among others. A conspicuous impact of copper toxicity is thickening of root apices in Pinus seedlings, inhibition of production of root hair in Betula papyrifera, and seedlings of Lonicera tatarica (Arduini et al.1995; Patterson and Olson 1983). Excessive Cu causes production of some new roots and thickening of taproot in Citrus paradisi (Zhu and Alva 1993). Excessive Cu causes chlorosis in Banksia ericifolia (heath banksia), Casuarina distyla (she - oak) and Eucalyptus eximia (yellow bloodwood) (Mitchell et al.1988).

3.1.3 Zinc

Like other micronutrients, zinc (Zn) is an essential micronutrient for many metabolic processes of plants. However, beyond its optimum range (15–60 ppm), it adversely affects roots, shoots, seed germination, and flowering responses in French marigold (Choi et al.1996). Elevated levels of Zn in soil cause decline in the level of chlorophyll pigments leading to chlorosis in younger leaves. Zn toxicity promotes senescence and causes reduction in plant biomass (Mirshekali et al.2012). Moreover, it also acts as genotoxic pollutant by causing structural and numerical aberrations in chromosome of plants, thus affecting cell division (Sharma and Talukdar 1987).

3.1.4 Manganese

Manganese (Mn) is an important micronutrient and cofactor of enzymes required in photosynthesis. However, excess amount of this heavy metal causes reduction in plant growth and visible symptoms like leaf bronzing and shortening of internodes (Crawford et al.1989). While Mn concentration in the range of 500 μM caused reduced shoot growth in rice, soybean showed chlorosis at a concentration of 200 μM (Lidon and Teixeira 2000; Lavres et al.2009).

3.1.5 Cobalt

Cobalt (Co) occurs naturally in earth's crust in the form of erythrite [Co3 (AsO4) 2], cobaltite [CoAsS] and smaltite [CoAs2] (Nagajyoti et al.2010). The effects of Co toxicity have been studied in various crops like barley, tomato, and oilseed rape, where it has been found to inhibit biomass and shoot growth (Li et al.2009). Excess Co causes leaf distortion, giving an appearance of a structure like hook with rudimentary leaflets. Exogenous application of Co to tomato leaves leads to greatest accumulation of this heavy metal in roots and older leaves, while, lowest in stem. The plant showed altered enzymatic activity of peroxidase, catalase, ribonuclease, and acid phosphatase (Gopal et al.2003). Co toxicity also causes decreased transpiration rate and water potential, an effect that is not found in Cu or Cr toxicity.

3.1.6 Nickel

Nickel (Ni) acts as a cofactor of urease, the enzyme which metabolizes urea into ammonia (usable form of nitrogen) within plants. Deficiency of Ni causes accumulation of toxic urea within the tissue and formation of necrotic legions on the leaf tips (Bhalerao et al.2015). This enzyme helps in nitrogen fixation in many plant species. Ni also helps in disease tolerance (Sengar et al.2008), but the mechanismis not very clear. Deficiency of this mineral nutrient causes reduction in size of leaflets with small rounded tips; this condition is called mouse - ear. At higher concentration (>50 μg/g dry weight), Ni acts as a phytotoxic metal and adversely affects growth in many plant species (Crooke 1956). Ni is reported to inhibit gas exchange and photosynthesis in plants such as maize and sunflower (Lo and Chen 1994; Mishra et al.1973). Seregin and Kozhevnikova (2006) reported effect of Ni toxicity on wheat and found 1 mM NiSO4 solution causes decrease in the mesophyll thickness, reduction in size of vascular bundles, change in vessels diameter etc.

3.2 Heavy Metals That Are Not Vital for Plant Growth

Other heavy metals like lead, arsenic, manganese, and cadmium are highly deleterious to plants.

4. Effect of Heavy Metal Polluted Soil on Plant Growth:

The heavy metals that are available for plant uptake are those that are present as soluble components in the soil solution or those that are easily solubilized by root exudates (M. J. Blaylock and J. W. Huang, 2000). Although plants require certain heavy metals for their growth and upkeep, excessive amounts of these metals can become toxic to plants. The ability of plants to accumulate essential metals equally enables them to acquire other nonessential metals (R. Djingova and I. Kuleff, 2000). As metals cannot be broken down, when concentrations within the plant exceed optimal levels, they adversely affect the plant both directly and indirectly. Some of the direct toxic effects caused by high metal concentration include inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress (F. Assche and H. Clijsters 1990) & (C. D. Jadia and M. H. Fulekar 2009).

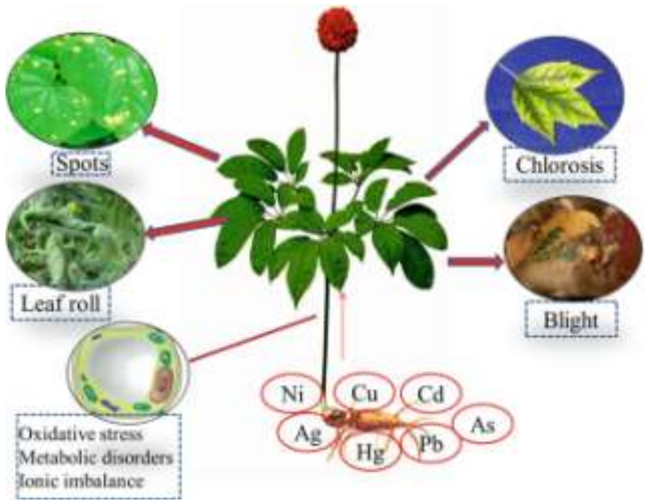

Figure 2: Metal toxicity on Plants

An example of indirect toxic effect is the replacement of essential nutrients at cation exchange sites of plants (L. Taiz and E. Zeiger 2002). Further, the negative influence heavy metals have on the growth and activities of soil microorganisms may also indirectly affect the growth of plants. For instance, a reduction in the number of beneficial soil microorganisms due to high metal concentration may lead to decrease in organic matter decomposition leading to a decline in soil nutrients. Enzyme activities useful for plant metabolism may also be hampered due to heavy metal interference with activities of soil microorganisms. These toxic effects (both direct and indirect) lead to a decline in plant growth which sometimes results in the death of plant (A. Schaller and T. Diez 1991).

5. Conclusion

Plants growing on heavy metal polluted soils show a reduction in growth due to changes in their physiological and biochemical activities. This is especially true when the heavy metal involved does not play any beneficial role towards the growth and development of plants. Due to that reason plan growth and development absent in the polluted areas.

6. Future Prospects and Recommendations

Heavy metal - contamination of agricultural land is one of the abiotic stresses that limit crop productivity. One of the strategies of tackling heavy metal toxicity in plants is to target the initial step of uptake of heavy metals by plants and encourage the bio remediation methods to identify the polluted areas.

The role of government and environment protection agencies is imperative in initiating awareness among people and formulating stringent laws in order to check the anthropogenic production of these heavy metals. The knowledge about harmful impacts of heavy metals on plant growth is very important not only for improved plant growth and yield, but also to achieve pollution - free environment and ecological harmony.

- Encourage research on remediation of ground water, Soil and Industrial solid waste contaminated sites in industrial areas.
- Phyto remediation is a better solution to this problem, it is environment friendly and ecologically responsible solar driven technology with good public acceptance.

Acknowledgements

The authors are thankful to Manipur International University, Imphal, India for providing a platform to write this review article. One of the authors (Srinivas Jonnalagadda, a post - doctoral researcher) is also grateful to SeniorProf. Potsangbam Kumar Singh, Former Professor, Centre of Advanced Study in Botany, Ethnobotany and Plant Physiology Laboratory, Department of Life Sciences, Manipur University, Imphal, Manipur, India and Prof. A. V. Purushotham, Principal (Retired), MSN Degree College, Kakinada, Andhra Pradesh, India for their constant encouragement and suggestions.

References

[1] Hawkes JS (1997) Heavy metals. J Chem Educ 74: 1369–1374.
[2] Tchounwou PB, Yedjou CG, Patlolla AK, Sutton DJ (2012) Heavy metal toxicity and the environment. In: Molecular, clinical and environmental toxicology. Springer, Basel, pp 133–164.
[3] Oliveira A, Pampulha ME (2006) Effects of long - term heavy metal contamination on soil microbial characteristics. J Biosci Bioeng 102 (3): 157–161.
[4] Khan AG, Kuek C, Chaudhry TM, Khoo CS, Hayes WJ (2000) Role of plants, mycorrhizae and phyto chelators in heavy metal contaminated land remediation. Chemosphere 41 (1–2): 197–207.
[5] Herawati N, Suzuki S, Hayashi K, Rivai IF, Koyoma H (2000) Cadmium, copper and zinc levels in rice and soil of Japan, Indonesia and China by soil type. Bull Environ Contam Toxicol 64: 33–39.
[6] Nagajyoti PC, Lee KD, Sreekanth TVM (2010) Heavy metals, occurrence and toxicity for plants: a review. Environ Chem Lett.8: 199–216.
[7] Eshleman A, Siegel SM, Siegel BZ (1971) Is mercury from Hawaiian volcanoes a natural source of pollution? Nature 223: 471–475.

[8] Nriagu JO (1989) A global assessment of natural sources of atmospheric trace metals. Nature 338: 47–49.

[9] Yanqun Z, Yuan L, Jianjun C, Haiyan C, Li Q, Schratz C (2005) Hyper accumulation of Pb, Zn and Cd in herbaceous grown on lead - zinc mining area in Yunnan, China. Environ Int 31: 755–762.

[10] Guan Q, Wang F, Xu C, Pan N, Lin J, Zhao R, Luo H (2018) Source apportionment of heavy metals in agricultural soil based on PMF: a case study in Hexi Corridor, northwest China. Chemosphere 193: 189–197.

[11] Lacerda LD (1997) Global mercury emissions from gold and silver mining. Water Air Soil Pollut 97: 209–221.

[12] Nagajyoti PC, Lee KD, Sreekanth TVM (2010) Heavy metals, occurrence and toxicity for plants: a review. Environ Chem Lett.8: 199–216.

[13] Verkleji JAS (1993) The effects of heavy metals stress on higher plants and their use as bio monitors. In: Markert B (ed) Plant as bioindicators: indicators of heavy metals in the terrestrial environment. VCH, New York, pp 415–424.

[14] Tchounwou PB, Yedjou CG, Patlolla AK, Sutton DJ (2012) Heavy metal toxicity and the environment. In: Molecular, clinical and environmental toxicology. Springer, Basel, pp 133–164.

[15] Angino EE, Magnuson LM, Waugh TC, Galle OK, Bredfeldt J (1970) Arsenic in detergentspossible danger and pollution hazard. Science 168: 389–392.

[16] Tangahu BV, Abdullah S, Rozaimah S, Basri H, Idris M, Anuar N, Mukhlisin M (2011) A review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. Int J Chem Eng 2011: 939161: 1–31. https: //doi. org/10.1155/2011/939161

[17] Shahid M, Dumat C, Khalid S, Schreck E, Xiong T, Niazi NK (2017) Foliar heavy metal uptake, toxicity and detoxification in plants: a comparison of foliar and root metal uptake. J Hazard Mater 325: 36–58.

[18] Phaniendra A, Jestadi DB, Periyasamy L (2015) Free radicals: properties, sources, targets, and their implication in various diseases. Indian J Clin Biochem 30 (1): 11–26.

[19] Gall JE, Boyd RS, Rajakaruna N (2015) Transfer of heavy metals through terrestrial food webs: a review. Environ Monit Assess 187 (4): 201.

[20] Mourato MP, Moreira IN, Leitão I, Pinto FR, Sales JR, Martins LL (2015) Effect of heavy metals in plants of the genus Brassica. Int J Mol Sci 16 (8): 17975–17998.

[21] Misra SG, Mani D (1991) Soil pollution. Ashish Publishing House, New Delhi.

[22] Marschner H (1995) Mineral nutrition of higher plants, 2nd edn. Academic Press, Toronto.

[23] De Dorlodot S, Lutts S, Bertin P (2005) Effects of ferrous iron toxicity on the growth and mineral composition of an inter specific rice. J Plant Nutr 28: 1–20.

[24] Singh PK, Tewari SK (2003) Cadmium toxicity induced changes in plant water relations and oxidative metabolism of Brassica juncea L. plants. J Environ Biol 24: 107–117.

[25] Neelima P, Reddy KJ (2002) Interaction of copper and cadmium with seedlings growth and biochemical responses in Solanum melongena. Nat Environ Pollut Technol 1: 285–290.

[26] Ouzounidou G (1994) Change in chlorophyll fluorescence as a result of copper treatment: dose response relations in Silene and Thlaspi. Photosynthetica 29: 455–462.

[27] Arduini I, Godbold DL, Onnis A (1995) Influence of copper on root growth and morphology of Pinus pinea L. and Pinus pinasterAit. seedlings. Tree Physiol 15: 411–415.

[28] Patterson WA, Olson JJ (1983) Effects of heavy metals on radicle growth of selected woody species germinated on filter paper, mineral and organic soil substrates. Can J For Res 13 (2): 233–238.

[29] Zhu B, Alva AK (1993) Distribution of trace metals in some sandy soils under citrus production. Soil Sci Soc Am J 57: 350–355.

[30] Mitchell RL, Burchett MD, Pulkownik A, McCluskey L (1988) Effects of environmentally hazardous chemicals on the emergence and early growth of selected Australian native plants. Plant Soil 112: 195–199.

[31] Choi JM, Pak CH, Lee CW (1996) Micronutrient toxicity in French marigold. J Plant Nutr 19: 901–916.

[32] Mirshekali H, Hadi H, Amirnia R, Khodaverdiloo H (2012) Effect of zinc toxicity on plant productivity, chlorophyll and Zn contents of sorghum (Sorghum bicolor) and common lambsquarter (Chenopodium album). Int J Agric Res Rev 2: 247–254.

[33] Sharma A, Talukdar G (1987) Effects of metals on chromosomes of higher organisms. Environ Mutagen 9: 191–226.

[34] Crawford TW, Stroehlein JL, Kuehl RO (1989) Manganese and rates of growth and mineral accumulation in cucumber. J Am Soc Hort Sci 114: 300–306.

[35] Lavres J, Malavolta E, Nogueira NL, Moraes MF, Rodrigues A, Lanzoni M, Pereira C (2009) Changes in anatomy and root cell ultrastructure of soybean genotypes under manganese stress. Rev Bras Cienc Solo 33: 395–403.

[36] Nagajyoti PC, Lee KD, Sreekanth TVM (2010) Heavy metals, occurrence and toxicity for plants: a review. Environ Chem Lett.8: 199–216.

[37] Li HF, Gray C, Mico C, Zhao FJ, McGrath SP (2009) Phytotoxicity and bioavailability of cobalt to plants in a range of soils. Chemosphere 75: 979–986.

[38] Gopal R, Dube BK, Sinha P, Chatterjee C (2003) Cobalt toxicity effects on growth and metabolism of tomato. Commun Soil Sci Plant Anal 34: 619–628.

[39] Bhalerao SA, Sharma AS, Poojari AC (2015) Toxicity of nickel in plants. Int J Pure and Appl Biosci 3 (2): 345–355.

[40] Sengar RS, Gupta S, Gautam M, Sharma A, Sengar K (2008) Occurrence, uptake, accumulation and physiological responses of nickel in plants and its effects on environment. Res J Phytochem 2 (2): 44–60.

[41] Crooke WM (1956) Effect of soil reaction on uptake of nickel from a serpentine soil. Soil Sci 81 (4): 269–276.

[42] Lo TY, Chen SM (1994) The effect of chemical treatment on the carotene and ascorbic acid contents of tomato. J Chin Chem Soc 11: 95–98.

[43] Mishra D, Kar M, Pradhan PK (1973) Chemical regulation of acid inorganic pyrophosphates activity during senescence of detached leaves. Exp Gerantol 8: 165–167.
[44] Seregin IV, Kozhevnikova AD (2006) Physiological role of nickel and its toxic effects on higher plants. Russ J Plant Physiol 53: 257–277.
[45] M. J. Blaylock and J. W. Huang, "Phytoextraction of metals, " in Phytoremediation of Toxic Metals: Using Plants to Clean up the Environment, I. Raskin and B. D. Ensley, Eds., pp.53–70, Wiley, New York, NY, USA, 2000.
[46] R. Djingova and I. Kuleff, "Instrumental techniques for trace analysis, " in Trace Elements: Their Distribution and Effects in the Environment, J. P. Vernet, Ed., Elsevier, London, UK, 2000.
[47] F. Assche and H. Clijsters, "Effects of metals on enzyme activity in plants, " Plant, Cell and Environment, vol.24, pp.1–15, 1990. [29] C. D. Jadia and M. H. Fulekar, "Phytoremediation of heavy metals: recent techniques, " African Journal of Biotechnology, vol.8, no.6, pp.921–928, 2009.
[48] L. Taiz and E. Zeiger, Plant Physiology, Sinauer Associates, Sunderland, Mass, USA, 2002.
[49] A. Schaller and T. Diez, "Plant specific aspects of heavy metal uptake and comparison with quality standards for food and forage crops, " in Der Einfluß von festen Abfallen auf B¨ oden, ¨Pflanzen, D. Sauerbeck and S. Lubben, Eds., pp.92–125, KFA, ¨ Julich, Germany, 1991, (German).

Author Profile

Dr. J. Srinivas is a post - doctoral research student in Manipur international University, India, took Doctor of philosophy from JNTUK Kakinada in 2018, received dual Master's degree from Andhra University and Acharya Nagarjuna Universities, Andhra university, India, published 27 research papers in various international journals, research of interest in Phyto - remediation, Plant uptake and Bio remediation methods, also interesting in Taxonomy and plant physiology subjects in Botany, participated, attended & presented 12 research papers in various national, international conferences and seminars, 15 years of research experience and also having 13 years of Oil and Gas, Mining, Pharmaceutical and Chemical industrial experience.

Prof. A. V. Purushotham (Retired) was a principal in M. S. N. Degree College, Kakinada, Andhra Pradesh, India, had Doctor of philosophy from Andhra University, Visakhapatnam, Andhra Pradesh on 2005, received Master of Science in Botany (Specialization in Plant Taxonomy) from South Gujarat University, Suat, Gujarat, India, took B. Ed., from Andhra University, published 26 research papers in various international journals, research of interest in Phyto - remediation, Plant uptake and Bio remediation methods, also interesting in Taxonomy and subject in Botany, participated, attended & presented 12 research papers in various national, international conferences and seminars, also having 34 years of teaching experience in Botany and Environmental Science departments.

Senior Prof. Potsangbam Kumar Singh, Former Professor, Centre of Advanced Study in Life Sciences, Ethnobotany and Plant Physiology Laboratory, Department of Botany, Manipur University, Imphal, Manipur, India. At present he is working as a Senior Professor cum Research Officer, Department of Botany, Manipur International University, Imphal, - 795 140, Manipur, India. He received Doctor of Science from International Open University, Colombo, having well experience in teaching, research pursuits and published 167 research papers in various international Journals.