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ARSENIC POLLUTION: AN ENVIRONMENTAL PROBLEM

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ABSTRACT

Arsenic, a toxic metalloid occurs naturally, being the 20th most abundant element in the earth's crust. Arsenic and its component are mobile in the environment. Arsenic enters into the environment mainly from industrial processes, phosphate fertilizer and atmospheric deposition. It is highly toxic to the crop plants as well as human beings. Arsenic contamination in the soil may cause a variety of problems such as loss of vegetation, ground water contamination etc. Groundwater contamination by arsenic is a serious threat to mankind and plants all over the world. Two forms of arsenic are present in the environment *viz*., inorganic and organic. Inorganic arsenic is more toxic than organic arsenic. Arsenic toxicity severely affects the growth and development of plants resulting in perturbation in various physiological and chemical processes which ultimately poses a threat to the environment. In this way arsenic pollution is becoming a serious environmental problem in the world which needs more research towards its detoxification.

KEYWORDS: Arsenic, Environment, Pollution, Phytotoxicity, Crop plants.

Arsenic is ubiquitous in the environment. Arsenic contamination in soil often leads to ground water contamination and arsenic toxicity in plants, human and animals. Arsenic originates from anthropogenic and geochemical sources (Smith et al., 1992, 1998). Human activities have caused an accumulation of arsenic in soil through use of arsenic-based pesticides, manufacturing of arsenic-based compounds, smelting of arsenic ores, mining processes and fuel utilization. Plants represent the primary route by which arsenic enters terrestrial food webs. Arsenate and arsenite are two major forms of arsenic available in the soil and both forms are inter-convertible (Meharg and Hartley-Whitaker, 2002). Arsenate is taken up through carrier mediated phosphate translocation system and arsenite is taken up by plants through aquaporins. Arsenite after being taken up by plants causes damage to root membranes, inhibit cellular functions, induces oxidative stress and even causes cellular death. Arsenite is regarded as more toxic than arsenate for plants in terms of root length and shoot height etc (Stoeva et al., 2003, 2005).

Depression of plant growth and development has often been observed as a result of high levels of arsenic additions to soils and groundwater in arsenic-contaminated areas. It is not considered as an essential element for plant growth. Plants vary considerably in their tolerance to high levels of soil arsenic. Plants take up arsenic from the solution phase of soils. Bioaccumulation of arsenic is hazardous to humans and animals because of its possible relationship to cancer, arteriosclerosis, chronic liver disease etc. The highest concentrations of arsenic are found in plant roots, intermediate levels in vegetative tissue and the lowest levels in reproductive tissue (Stoeva et al., 2003, 2005). Toxicity to animals or humans usually is due to the ingestion of arsenic accumulated plant materials (Kile et al., 2007).

OCCURRENCE OF ARSENIC

Source of arsenic in the environment includes natural and anthropogenic (Smith et al., 1992, 1998). Arsenic is occurred ubiquitously throughout earth crust, soil, sediments, water, air and living organisms. Arsenic is a rare crystal element in earth crust and the average concentration of arsenic in igneous and sedimentary rocks is 2 mg kg^{-1}. In most rocks it ranges from 0.5 to 2.5 mg kg^{-1}. Higher concentrations are found in fine-grained argillaceous sediments and phosphorites (Kabata-Pendias and Pendias, 1984). Arsenic is present in soils in higher concentrations than those in rocks. Uncontaminated soils usually contain 1-40 mg kg^{-1} of arsenic. Arsenic is present at low concentration in natural water. The permissible concentration of arsenic in drinking water is 50 µg l^{-1} and recommended value is 10 µg l^{-1} by EPA and WHO. Arsenic may accumulate in soil and water through use of arsenical pesticides, application of fertilizers, dust from the burning of fossil fuel, disposal of industrial and animal wastes (Smith et al., 1992, 1998).

ARSENIC CHEMISTRY AND ITS TOXICITY

Arsenic is a toxic metalloid and occurs predominantly in inorganic and organic forms and in different valence or oxidation states in the environment. Arsenic is present in the natural system in four oxidation states such as -3, 0, +3 and +5 with different physical and chemical properties. Organic species are less toxic than inorganic species. With different physical and chemical properties, the various chemicals forms of arsenic available are arsenate (v), arsenite (III), monomethyl arsenic acid (MMA), dimethylarsenic acid

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(DMA), trimethylarsenic acid (TMA), arsenocholine (AsC), arsenobetaine (AsB), arsenosugars etc. Arsenate and arsenite are the two major inorganic form of arsenic in soil and both forms are interconvertible depending on the redox conditions (Meharg and Hartley-Whitaker, 2002). Trivalent oxidation state is more toxic than that in the pentavalent state. Arsenate exists in aqueous solution as H_3AsO_4, $H_2AsO_4^-$, $HAsO_4^{2-}$ and AsO_4^{3-}, while arsenite is present in reducing conditions eg. in anaerobic ground water (Fowler, 1977). In aqueous solution it occurs mainly as H_3AsO_3.

Arsenic is highly toxic to plants and animals including humans. Arsenic, being a normal compound of human body and it is transported by blood to different organs in the body. It causes a variety of adverse health effects to human after acute and chronic exposures such as dermal changes (pigmentation, hyperkeratosis), respiratory, pulmonary, cardiovascular, gastrointestinal, haematological, neurological, mutagenic and carcinogenic effects (NRC 1999, 2001). Arsenic toxicity adversely affects the growth of root and shoot in plants. Toxicity of arsenic causes harmful effect on seedling growth, root anatomy, lipid peroxidation, electrolyte leakage, H_2O_2 content, root oxidizability and the activities of antioxidant in plants. Exposure to inorganic arsenic species results in the generation of reactive oxygen species (superoxide radical, hydroxyl radical and hydrogen peroxide), which can directly damage protein, amino acids, nucleic acids and can cause peroxidation of membrane lipids (Stoeva et al., 2003, 2005). Arsenate and arsenite are phytoavailable forms of arsenic. Arsenate and phosphate are chemically similar allowing arsenate to act as analogue thereby permitting transport in to the cell (Meharg and Macnair, 1990). Being analogue to phosphate, arsenate replaces phosphate in ATP to form unstable 'ADP-As' complex and leads to the disruption of energy flow in cells. Arsenite binds to protein with sulfhydryl groups and interfere with their functions. It inhibits respiration by binding to vicinyl thiols in pyruvate dehydrogenase and 2-oxoglutarate dehydrogenase. Arsenic does not act directy as a mutagen but induces intrachromosomal homologous recombination and generation of reactive oxygen species (ROS). Arsenic is taken up by the plants as arsenate but the formation of ROS probably occurs through the conversion of arsenate to arsenite. The ROS formation process leads to the synthesis of enzymatic antioxidant; superoxide dismutase (SOD), catalase (CAT), and glutathione-S-transferase (GST), and non-enzymatically antioxidants; glutathione and ascorbate. Being a strong oxidizing agent, ROS induces oxidative stress to the biomolecules and finally bring about cell death (Hartley-Whitaker et al., 2001). Arsenite is highly toxic to plants as it reacts with sulfhydryl group (-SH) of enzyme and tissue protein leading to inhibition of cellular function which results in to cell death (Stoeva et al., 2003, 2005).

CONCLUSION

This review deals with environmental origin, occurrence, chemistry, and impact on living beings of arsenic. The metalloid arsenic is a natural environmental contaminant to which plants and animals are routinely exposed in food, water, air, and soil. The exposure pathways of arsenic to humans are dietary and drinking water which leads to many health problems. The exposure of crop plants to arsenic stress has become one of the major threats worldwide and needs an immediate action against its rapid contamination. The accumulation of arsenic in plants not only affects the plant growth but also enters the food chain, which in turn, causes potential health risks to human beings. There are some arsenic-hyperaccumulating plants, which would be useful in reducing arsenic pollution in agricultural soils. The people should be made aware of the arsenic problem and its effects, and their whole-hearted participation is also needed to control such situation. This knowledge will lead to better protection of environment at risk from arsenic-pollution.

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