



Chapter 5

Heavy metals in agro-ecosystems and their impacts on human health

Shefali^{1,*}, Sudhanshu Bala Nayak² and R.K. Gupta³

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Abstract

Heavy metals are proved to be a major threat and their toxic effects have various effects on living organisms including health risks in humans. Even though the heavy metals do not have any biological role but they are present in some form which is harmful for humans and impairs with the proper functioning. Most of the times heavy metals interfere with the metabolic processes for example some heavy metals get accumulated in the food chain and do not undergo degradation exhibiting a chronic nature. Heavy metals toxicity is largely dependent upon the absorbed dose, the route of exposure and the time duration of exposure whether it is acute or chronic which can

✉ Shefali, Email: shefaligulliya@gmail.com

^{1,3} Department of Zoology & Aquaculture, CCS Haryana Agricultural University, Hisar (Haryana), INDIA

² Department of Entomology, CCS Haryana Agricultural University, Hisar (Haryana), INDIA

result in excessive damage due to oxidative stress induced by free radical formation. Several public health measures have been put forward to control, prevent and treat metal toxicity occurring in the environment.

Keywords: Heavy metals, Agro-ecosystems, Toxic elements, Health risks, Pollution

Introduction

Soil is an important compartment of the environment which plays many functions in supporting life on planet earth. Some of the important functions of soil includes: ecological functioning (provide habitat to the flora and fauna and plays an important role in contributing to the element cycling), bearing function (playgrounds and buildings), biomass production (vegetation and crop production), also serve as raw materials for mining and construction and for archaeological and paleontological research. The quality of soil directly influences the groundwater which may be used for drinking water or surface water recharge (De Haan and F.A.M, 1996; Blum, 1990; Harris et al., 1996). Soil receives significant amount of pollutants from various sources every year, not only chemical pollutants are released into the soil; it also controls the natural transport of chemical substances in to the environment. With the advancement in techniques the standards of life have improved and it results in raising new challenges to the safety of environment as unrestricted industrialization have put the lives of living organisms at risk without proper emission control mechanisms (Kabata-Pendias and Pendias, 2001).

Agro-ecosystem includes the land where humans cultivate different kinds of plants which is used in food or in industry. In addition to the cultivated plants the agro-ecosystem possess different types of wild plants, animals, fungi and micro-organisms. Agro-ecosystem is largely contaminated with different types of toxicants by various sources which negatively affect the flora and fauna of soil and in addition to these higher trophic levels of food chain is also disturbed. The soil contamination can be distinguished in to two types: point source and non-point source contamination. Point source contamination is caused by single source for example pollution by accidental or deliberate human activities whereas non-point source is large scale contamination which is caused by a particular source or a combination of different sources for example sewage sludge in agriculture and fertilizer and heavy metal pollution of soil (Huang et al., 2007). Thus the agro-ecosystem is largely contaminated with various different kinds of hazardous toxicants out of which heavy metals are most important as due to their increased concentrations in soil they get accumulated in plants and thus reaches to different trophic levels through food chain and produce a range of health problems (Zheng et al., 2005).

The heavy metals usually bind with the protein sites which are not made for them by displacing the original metals from their natural binding sites which results in disrupting the normal functioning of cells causing oxidative damage which can lead to DNA damage at certain high levels (Flora et al., 2008).

Heavy metals in agro-ecosystems

The exemplary definition of a metal refers to the physical properties of the elemental state, for example: ductility, electrical conductivity etc. The term heavy metal is often used to mean any metal with atomic number <20 (Davies, 1980). Heavy metals are naturally occurring elements that have a high atomic weight and a density at least 5 times greater than that of water (Fergusson, 1990). The heaviness and toxicity are presumed to be inter-related thus heavy metals including metalloids, such as arsenic induce toxicity even at low level of exposure. They are naturally occurring elements found throughout the earth's crust. Several reports have advocated that as cobalt (Co), copper (Cu), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se) and zinc (Zn) are essential nutrients that are necessary for various biochemical and physiological functions and their inadequate amount can cause variety of diseases or syndromes in humans. Heavy metals are potential environment toxicants posing risk to environment (Jaishankar *et al.*, 2013; Nagajyoti *et al.*, 2010). In addition to natural sources, the amount of metals entering the environment through anthropogenic sources has been increasing in recent years which are a major ecological and public health concern associated with environmental contamination by these metals (Bradl, 2002). Several studies reported the major sources of heavy metals are industrial, agricultural, domestic and technological applications (He Zl *et al.*, 2005), including soil erosion, natural weathering of rocks, mining, industrial effluents, urban run-off, sewage sludge discharge, pesticides applied to crops and many others (Morais *et al.*, 2012).

Source of heavy metals in agro-ecosystems

Heavy metals are comprised of heterogeneous group of elements which varies in their physico-chemical and biological properties. Heavy metals are found in a wide range of applications in our daily life and enter the environment mainly through anthropogenic activities such as mining, smelting, industrial and agricultural practices. Heavy metals are potential environmental pollutants because they are responsible for initiating a series of chain reactions that causes change in the quality of soil, water and atmosphere and are toxic to plants, animals and human beings. The entry of heavy metal in the environment and ultimately into the food chain at various trophic levels is an alarming concern to the human beings. Agro-ecosystem is contaminated with heavy metals through anthropogenic as well as natural activities. Natural sources of heavy metals include atmospheric emissions from volcanoes, continental dusts, weathering of rocks which are metal enriched (Ernst, 1998). Whereas, anthropogenic sources includes sewage sludge in agriculture fields, combustion, application of metal based pesticides or fertilizers, manufacture, use and disposal of electronics appliances i.e. mainly industrial, municipal and agricultural practices (Inogo *et al.*, 2013; Oves *et al.*, 2012). Heavy metals are highly toxic and they can build up in soil and get accumulated in the crops which ultimately

cause risk to human health (Huang *et al.*, 2007; Nguessan *et al.*, 2009). Soil contaminated with heavy metals from agricultural or industrial activities have raised serious concern nowadays regarding the risk to human health through the direct intake or bioaccumulation through food chain and ultimately their effect on ecological system.

Several studies have advocated that both essential heavy metals (copper, zinc and manganese) and non essential heavy metals (cadmium, chromium, manganese and lead) are highly toxic for human and aquatic life (Ouyang *et al.*, 2002).

Effect of heavy metals on human's health

Out of 35 metals 23 are heavy metals: arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc (Mosby *et al.*, 1996). All of these are commonly found in our environment and in small amounts they are essential for maintaining good health but in larger amount they can be toxic and cause damage. When the human is contacted with high doses of heavy metals for a longer duration this can result in lowering down the energy levels and for larger extent it is reported to damage the functioning of brain, lungs, kidney, liver and other important organs of body. The exposure to heavy metals is also known to cause several neurological disorder such as Parkinson's disease, Alzheimer's disease along with the physical impairments in human beings. Reports have been mentioned representing the fact that the repeated and long term exposure of heavy metals may even cause cancer (Jarup, 2003).

Effects of arsenic

The source of arsenic contamination includes both natural and anthropogenic processes. The human sources of arsenic pollution includes mining and ore processing, whereas the smelting process is also known to release arsenic in air as well as in soil (Matschullat, 2000). These sources usually affect the quality of surface water through groundwater run-off. Another source of arsenic pollution is through geological sources like arsenic minerals (Smedley and Kinniburgh, 2002). The inorganic forms of arsenic i.e. arsenite and arsenate are known to be more toxic to human health. Most of the times humans are exposed to these forms of arsenic by drinking water in more than 30 countries all over the world (Chowdhury *et al.*, 2000), water get contaminated by arsenic through disposal of chemicals, pesticides. These forms of arsenic are highly carcinogenic and are known to cause cancer of lungs, liver, bladder and skin. Several reports suggested that chronic toxicity in man mainly focuses on skin pigmentation (Martin and Griswold, 2009) and keratosis which is also known as "raindrops on a dusty road" (Smith *et al.*, 2000). The acute exposure of arsenic can cause nausea, vomiting, decrease in production of erythrocytes and leukocytes, abnormal heart beat etc, whereas chronic exposure results in irreversible changes in vital organs of the body of humans and the mortality rate is slightly higher (Mazumder, 2008; Shefali *et al.*, 2018).

Effects of lead

Anthropogenic activities like mining, burning of fossil fuels is the main reason for lead accumulation and other compounds in the environment mainly in air, water and soil. Lead is most commonly used in battery production, cosmetics etc. (Martin and Griswold, 2009). It is used in various products such as paints, gasoline and is highly toxic. One of the classic diseases caused by lead is its poisoning which is most common in children resulting in damaging the central nervous system and gastrointestinal tract (Markowitz, 2000). Most commonly lead poisoning occurs through drinking water, the pipes that carry the water may be made of lead and its compounds which contaminate the water (Brochin *et al.*, 2008). Lead is mainly considered as carcinogen according to the Environmental Protection Agency (EPA), and affects major organs of the human body. Acute exposure of lead mainly occurs in the place of work i.e. some manufacturing industries which uses lead and is known to cause loss of appetite, headache, hypertension, abdominal pain, renal dysfunction, fatigue, sleeplessness, arthritis, hallucinations and vertigo. When humans are exposed to lead for a longer duration of time it is known to cause mental retardation, allergies, psychosis, autism, dyslexia, hyperactivity, brain damage, kidney damage and at certain times may even known to cause death (Martin and Griswold, 2009).

Effects of mercury

Mercury poisoning is known as acrodynia or pink disease and it is considered as one of the most toxic heavy metal in the environment. Through anthropogenic sources mercury is released into the environment including the pharmaceuticals and agriculture industry (Morais *et al.*, 2012). Mercury usually combines with other elements and form organic and inorganic mercury. Chronic exposure to high levels of organic or inorganic mercury is known to damage the brain, kidneys and developing foetus (Alina *et al.*, 2012). Human nervous system is very sensitive of all types of mercury. Long time exposure to mercury is known to later the brain functions and leads to tremors, memory problems and in some cases change in vision or hearing. Symptoms of organic mercury poisoning include vomiting, nausea, increased heart rate or blood pressure, depression, memory problems, tremors, fatigue, headache, hair loss, etc (Martin and Griswold, 2009).

Effects of cadmium

Cadmium is basically a metal of the 20th century and is a byproduct of zinc pollution. Cadmium is mainly used in batteries, pigments, plastics and metal coatings for electroplating (Martin and Griswold, 2009) and it is also released in environment through natural activities like weathering of rocks, volcanic eruptions, and river transport. International Agency for Research on Cancer classified cadmium and its compounds as Group 1 carcinogens. Cadmium exposure to humans is highly toxic to kidneys as it accumulates in the proximal tubular cells when present in higher concentrations (Chakraborty *et al.*, 2013). Several studies advocated that cadmium causes disturbances in calcium metabolism leading to osteoporosis and is also known in formation of renal stones. If cadmium is inhaled in higher levels it can cause damage to lungs (Bernard, 2008).

Tobacco is the main source of cadmium intoxication as these plants accumulate cadmium from the soil at much higher pace thus; smokers are more susceptible to cadmium than non-smokers (Mudgal *et al.*, 2010).

Effects of chromium

Chromium is present everywhere even in rocks, soil, plants and animals. The chromium compounds can occur in various different states such as divalent, four-valent, five-valent and hexavalent state and can be present in solid, liquid or gas form. Cr(VI) and Cr(III) are the most stable forms and their relation to human exposure is highly studied (Zhitkovich, 2005). Cr(III) compounds are essential nutrient supplements for humans as well as for animals also and plays important role in glucose metabolism, whereas Cr(VI) compounds are highly toxic and carcinogenic in nature (Shefali *et al.*, 2019). Man-made sources of chromium includes metal coatings, metal alloys, magnetic tapes, paint pigments, rubber, cement, paper, wood preservatives, leather tanning and metal plating (Martin and Griswold, 2009). Exposure to chromium is known to cause ulcers, inhibition of erythrocyte glutathione reductase, which in turn lowers the capacity to reduce methemoglobin to hemoglobin (Koutras *et al.*, 1965; Schlatter and Kissling, 1973). Several studies have advocated that chromate compounds exposure can induce DNA damage (O'Brien *et al.*, 2001; Matsumoto *et al.*, 2006).

Effects of aluminum

Aluminum exists in only one oxidation state (3+) and it's the third most important element on the earth. Humans are exposed to aluminum through drinking water, food, beverages, and aluminum containing drugs. Aluminum exposure symptoms include: nausea, mouth ulcers, skin ulcers, skin rashes, vomiting and diarrhea. Aluminum mainly affects the nervous system of humans which results in loss of memory, problems with balance and loss of coordination (Krewski *et al.*, 2009).

Conclusion

The term metal toxicity or metal poisoning refers to the toxic effects of certain heavy metals in certain forms and doses on living organisms. In this chapter authors have briefed the toxic effects of certain heavy metals i.e. arsenic, lead, mercury, cadmium, chromium and aluminum on the living organisms, mainly human beings. Certain metals have no or little biological role and they are not even essential minerals but they are toxic to living organisms in a certain form. These heavy metals sometimes imitate the action of essential elements in the body thus, interfering with the metabolic process resulting in illness. Heavy metals do not undergo degradation as a result of this they get bio-accumulated in the body and in the food chain at certain trophic levels. Failure to control the level and dose of exposure leads to several adverse effects in humans. Thus, it is the need of the time to monitor the exposure and probable intervention for reducing the additional

exposure to heavy metals in the atmosphere and even in humans which can be a momentous step towards prevention.

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