ISSN: 2348-1900
Plant Science Today
http://www.plantsciencetoday.online

**Mini Review**

# Heavy metals and their general toxicity on plants

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*Article history*
Received: 16 October 2017
Accepted: 21 November 2017
Published: 01 January 2018



*Editor*
K K Sabu

*Publisher*
Horizon e-Publishing Group

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**Abstract**

Heavy metals are important environmental pollutants, and their toxicity is a serious problem of great concern for environmental, ecological, nutritional and toxicological reasons. Metals can affected long list of physiological and biochemical processes in plants and their toxicity varies with plant species, particular metal, metal concentration and it chemical form. Throughout the world, researches have been conducted extensive investigations to determine the effects of toxic heavy metals on plants. The process is still going on and the need of intensification of the research programmes for better understanding of heavy metal toxicity is evident.

**Keywords**

heavy metals; plants; toxicity

**Citation**

Ackova D G. Heavy metals and their general toxicity on plants. Plant Science Today 2018; 5(1):14-18. doi: https://dx.doi.org/10.14719/pst.2018.5.1.355

## Introduction

According to the definition, a general term “heavy metals” applies to the group of metals and metalloids with atomic density is greater than 4 g/cm$^3$, or is 5 times or more, greater than water density (1). In this group, lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co), iron (Fe), zinc (Zn), chromium (Cr), silver (Ag), arsenic (As), and the platinum group elements are included. There is also an alternative classification of metals which is based on their coordination chemistry. This classification categorizes heavy metals as class B metals that are non-essential trace elements and are highly toxic elements such as Hg, Ag, Pb, Cd and Ni.

Some of the heavy metals are bioaccumulative, they do not breakdown in the environment and they are not easily metabolized, which is the main reason for their accumulation in food chain at primary producers (through the uptake of plants) and at consumer levels (through consumption).

Fast economic development and increasing industrialization world wide cause the release of a wide range of xenobiotics into the atmosphere. Any xenobiotic in the environment, which causes undesirable effects, impair the welfare of the environment, reduce the life quality and eventually cause death of different organisms is named as a pollutant (2). This kind of xenobiotics has to be present in the environment beyond tolerance limit. Hence, heavy metals are important environmental pollutants, and their toxicity is a problem of great concern for environmental, ecological, nutritional and toxicological reasons. Heavy metals are considered as particularly relevant genotoxic agents due to their long term persistence in the environment.

Metals can affected long list of physiological and biochemical processes in plants and their toxicity

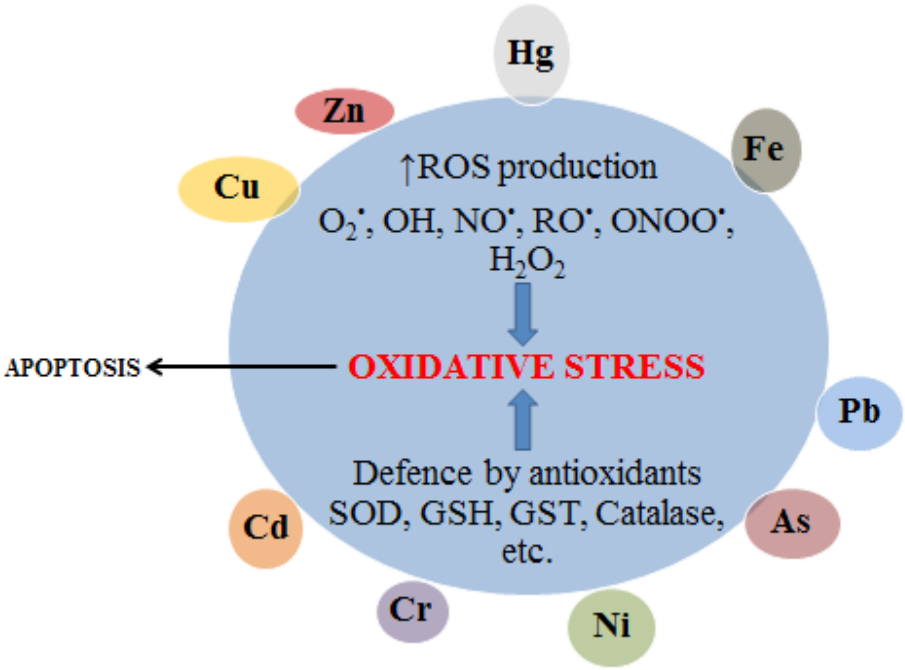


**Fig. 1.** Effect of heavy metal stress on antioxidant systems in plant cell

varies with plant species, particular metal, metal concentration and its chemical form. As many heavy metals are considered to be essential for plant growth, soil composition and pH are also importance. Some of the heavy metals, like Cu and Zn, serves as cofactors and enzyme activators, but others such as Cd, Hg and As, are extremely poisonous resulting in growth inhibition and death of organisms which are present at high concentrations. Roots of plants are the initial contact site for heavy metals but they are also absorbed directly to the plant leaves due to the deposition on its surfaces.

Because of the influence of the plant itself and environmental factors, the levels of heavy metals in plants can be widely different (3, 4). The data in Table-1 indicates very clear presentation of these findings. The comparison is made between the ranges of heavy metals observed in land plants (2) and regulatory standards for heavy metals in food and drinking water in different countries (5, 6).

## General toxic effects of heavy metals on plants

Throughout the world, researches have been conducted extensive investigations to determine the effects of toxic heavy metals on plants (7-18). Plants are sensitive both to the deficiency and sufficiency of some heavy metal ions including essential micronutrients and also strongly poisonous ones. Here, we have reviewed some facts about metal toxicity of selected metals in plants with intention to put point on issue which can have detrimental effects not only on plant itself, but also on human health as consequence.

### *Cadmium effects on plants*

Cadmium is very toxic element for all living organisms and as far as is known, and is not metabolically involved. Cadmium is an extremely mobile element in the soil, and easily transported through the plant and distributed to all plant organs subsequently (19-21).The normal limits of Cd contents in plants are stated between 0.2-0.8 mg $kg^{-1}$ and toxic concentrations of Cd are defined as 5-30 mg $kg^{-1}$ (20). Depending on their Cd content, plants are classified as Cd accumulators or Cd avoiders. Cd interfere with the uptake, transport and use of several elements (K, Ca, Mg, and P) by plants and also interact with the water balance (22). Containing high levels of Cd, plants show visible symptoms of toxicity reflected as chlorosis, growth inhibition, browning of roots and leads to death (18, 23-25). Cd inhibits enzyme activity in plants, as root Fe (III) reductase (led to Fe (II) deficiency and affect photosynthesis), nitrate reductase activity in the shoots (reduced the absorption of nitrates and its transport), enzymes involved in $CO_2$ fixation, etc.

### *Lead effects on plants*

Lead (Pb) is a non-essential element which cause phytotoxicity on plants for long time ago, and its adverse effects on morphology, seed germination, seedling growth, photosynthesis, water content, mineral nutrition, and enzymatic activities are confirmed for all plant species (12, 19, 26-31). As a general rule, the effects are more noticeable at high concentrations of Pb and duration of exposure. The primary toxic effect of Pb is find in its extensive reaction with sulfhydryl groups which cause inhibition of enzyme activity and its

Table 1: Ranges of heavy metals content in land plants and regulatory standards for heavy metals in food and drinking water in different countries (Europe, India, Canada & China)

| Elements | Content measured in different plants (µg/g dw) | Indian standards | | Canada (in row herbal materials) (mg/kg) | WHO (mg/kg) | China (herbal material) (mg/kg) |
|---|---|---|---|---|---|---|
| | | Food (mg/kg) | Water (mg/L) | | | |
| As | 0.02-7 | 1.1 | 0.05 | 5 | Nil | 2 |
| Cd | 0.1-2.4 | 1.5 | 0.01 | 0.3 | 0.3 | 1 |
| Hg | 0.005-0.02 | Nil | Nil | 0.2 | Nil | 0.5 |
| Pb | 1-13 | 2.5 | 0.1 | 10 | 10 | 10 |
| Co | 0.05-0.5 | Nil | Nil | Nil | Nil | Nil |
| Cr | 0.2-1 | 20 | 0.05 | 2 | Nil | Nil |
| Cu | 4.15 | 30 | 0.05 | Nil | Nil | Nil |
| Fe | 140 | Nil | 0.03 | Nil | Nil | Nil |
| Mn | 15-100 | Nil | 0.1 | Nil | Nil | Nil |
| Ni | 1 | 1.5 | Nil | Nil | Nil | Nil |
| Zn | 8-100 | 50 | 5.0 | Nil | Nil | Nil |

induction effect on reactive oxygen species (ROS) production which cause oxidative stress (11, 32, 33).

### *Arsenic effects on plants*

Arsenic is a non-essential and generally toxic element to plants, which inhibits root extension and proliferation, inhibits biomass production, interfere with metabolic processes (As is an analog of phosphate (P) and competes for the same uptake carriers) and can severely inhibit plant growth by compromising plant reproductive capacity (34, 35). The molecular mechanisms of generation of physiological responses to As exposure are not clear. On one side of As toxicity phenomena is fact that plant growth is stimulated at low concentrations of As and on the other side, the plants that are naturally tolerant and hyper-accumulate As (35-39). Arsenic exposure generally induces the production of reactive oxygen species (ROS) that can lead to oxidative stress. The binding of As (III) to proteins can have profound effects on their folding. Among proteins that are known to bind As (III) are transcription factors, signal transduction proteins, metabolic enzymes, redox regulatory enzymes, and structural proteins (40, 41).

### *Zinc effects on plants*

Zinc is an essential element for all living organisms and plays an important role in the biosynthesis of enzymes, auxins and other proteins on plants. The range of 300-400 mg $kg^{-1}$dw is accepted as toxicity limit for Zn in plants, but there are variations according plant species and growth stage (20). Generally, Zn is not considered to be highly phytotoxic metal, but contents of Zn found in surrounding contaminated soils frequently exceed the required as nutrients and may cause phytotoxicity. The main signs of Zn toxicity in various plant species (which is also relevance for Cd phytotoxicity) are indicated by decrease in growth (both roots and shoots) and development of the plant, alteration in metabolism processes and induction of oxidative damage (18, 31, 42-45). Zinc toxicity also causes chlorosis, at beginning of exposure in the younger leaves, and after prolonged exposure, chlorosis is extended to older leaves also (46).

## Effects of heavy metals on antioxidant activity in plants

Besides the fact that antioxidant systems composed of antioxidants and specific enzymes, are being studied extensively, still some important intrinsic mechanisms and characteristics about this network remain unknown (47-50). The stress that heavy metals have on antioxidant system and plant cell is presented on Fig. 1. The main toxic effects of heavy metals over antioxidant system are seen in the increase in activity of some enzymes, depletion of depot of low molecular weight antioxidants and generation of ROS. There is a variety of studies in various plant species subjected to heavy metal stress that reported the antioxidant activity effects on plants (2, 17, 51, 52). Heavy metals can interfere with the antioxidants level in plants, can reduce the nutritive value, and because dietary intake of heavy metals through consumption of plants is not negligible and can have detrimental effects on human health.

## Conclusion

Heavy metals and their toxicity on plants and other living organisms are present above certain limits are in focus of the researches long time ago. The importance of this topic is evidences by the fact that the process is still going on. The need of intensification of the research programmes for better understanding of heavy metal toxicity is evident, and this goal must be reached if final effect for improving the welfare of biosphere is wanted.

## Conflict of interest

The author declare that have no competing interests.

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