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Metal Bioaccumulation/Toxicity Test for Metal Industry Wastewaters

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Abstract: Metal industry wastewaters include different types of heavy metals with respect to the metal production processes and products. There are several methods used for metal production industry such as refining and smelting operations. Both may produce air emissions like SO_2 and particulate matter, wastewater originating from floatation and leachate, and other wastes like sludge and slag. Heavy metals of metal industry wastewaters are nickel, brass, chrome, gold, cadmium, copper, brass, and silver. Most of them may give severe damage to human and environment. For example, chrome ion leads to lung cancer, stomach ulcer, kidney and liver function disorders and death on human. Thus, heavy metal containing wastewaters could be very dangerous. Besides, plant species which have capability of accumulate heavy metals can be an option to bioaccumulate metal industry wastewaters while plant species which are sensitive to heavy metals can be used as a plant for phytotoxicity tests. In this study metal industry wastewaters were analysed in order to determine plant species whether they are sensitive or tolerant to heavy metals. During analysis phytotoxicity tests were conducted with different plant species.
Keywords: Metal Wastewaters, Bioaccumulation, Heavy Metals, Toxicity.

INTRODUCTION

Heavy metals found in wastewaters mainly originating from metal industry and mining activities. The main pollution sources from metal industry originating from metal smelting and metal refining activities. The main purpose of metal working industries is obtaining instruments, machinery, machine components and tools that are necessary for economic purposes. Moreover, there are several different techniques present for metal manufacturing process such as casting, hammering, welding, cutting and shaping of metals [1]. Environmental consequences of smelting and refining of heavy metal ores are considerable. Especially three heavy metals namely copper, lead and zinc are very problematic pollution sources. They can produce SO_2 emissions and particulate matter, wastewater coming from leachate and wash down waters, and other wastes such as sludge and slag production. These pollutants are very harmful for the environment around the metal industries and with the help of wastewater, negative impacts may be transported to different areas [1].

Heavy metals linked with significant effects on human health are lead, mercury, arsenic, copper and cadmium [2]. These heavy metals could be found in different sources and human exposure is possible from air, water, plants and especially soil. When the concentration of heavy metals reached to toxic levels, consequences could be dangerous such as paralysis, stomatitis, tremor, diarrhoea, haemoglobinuria, gastrointestinal (GI) disorders, paralysis, vomiting depression, and pneumonia because of inhalation of gaseous products and particulate matters [3]. Furthermore, cancer formation is possible long-term effect of continuous heavy metal accumulation by humans [2]. Therefore, it is very important to understand heavy metal content of what we are exposed.

Bioaccumulation of heavy metals is important for decreasing the effects of them minimum. It is one of the cheapest and easiest way of reduction of pollution amount. Different plant species could be used as bioremediation material. To determine which plant is appropriate especially for heavy metal pollution, several techniques are used. Toxicity tests are the mostly used technique for understanding response of the plants. In this paper, different studies which have investigated several plant species were reviewed and their response against heavy metals were compared. Main heavy metals considered are lead (Pb), cadmium (Cd), zinc (Zn), copper (Cu), mercury (Hg). Different plants such as *Zea mays L., Lepidium sativum, Lolium perenne, Lactuca sativa* etc. have given variant of reaction against increasing concentrations of heavy metals.

MATERIAL AND METHOD

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Phytotoxicity tests are very important to understand tolerance of some plant species against different toxic materials. The main idea behind this test is understanding the capacity of a compound to cause temporary or permanent damage to plants [4]. There are several tests which have been developed for this purpose. Main standard methods used for phytotoxicity test are ISO 11269-2 (Effects of chemicals on the emergence and growth of higher plants), OECD 208 (Guideline for the testing of chemicals), CEN/TC 223 (Biotest for assessment of phytotoxicity), ÖNORM S 2021 (Quality Requirements and test methods), VDLUFA (Evidence of phytotoxic and gaseous phytotoxic substances in soils, horticultural substrate and composts). These methods are described as standards or draft standards for phytotoxicity testing [5]. They are developed by different countries with respect to the regulatory requirements or scientific projects.

ISO 11269-2 Method

This method was developed in 2005 and revised in 2012 by Technical Committee ISO/TC 190. The main purpose of this method is evaluation of the unknown soil quality and habitat function by monitoring the growth of two different plant species compared with standard control soils. Also, the method is appropriate for the soils of unknown quality such as soils from contaminated sites and soils after remediation [6]. This method is applied in specific places like green houses and plant growth rooms. Also, the containers used for planting has some specific features with respect to plant species used for tests. Rye, ryegrass, perennial, rice, oat, wheat, soft, barley, Sorghum, Sweetcorn, mustard, radish, turnip, Chinese cabbage, birds foot fenugreek, Lettuce, Cress, garden, Tomato, Bean are the main plant species which may be used for application of tests. Test parameters considered are number of seedlings emerging, number of plants remaining at harvest and total mass (fresh or dry) at harvest [5]. ISO 11269-2 Method is suitable for understanding the effects of chemicals on the emergence of and growth of higher plants.

OECD 208 Method

It is the mostly used method for the assessment of potential effects of different substances on seedling emergence and growth of plants. OECD Guidelines are updated periodically within the scope of scientific renewals and new regulations. Sandy loam, loamy sand and sandy clay loam soil including maximum 1.5 percent organic carbon are the main soil typeswhich can be used as a medium for plant growth. Generally, dicotyledonae such as sugar beet, mustard, cabbage, turnip, cucumber, tomato, soybean and monocotyledonae such as rice, corn, onion, wheat, barley family plant species are used in this method. The effects of test material on the plant growth are assessed following 14 to 21 days before the plantation. The main visual evaluation criteria of the method are emergence of seedling and biomass, and presence of detrimental effects such as chlorosis, mortality, abnormalities in plant development. Weekly measurements are done for comparison of seedlings with the control group [7]. Schematic representation of OECD Method is given in Figure 1.

Other Techniques

Moreover, there are other analyses which can be used for investigating the tolerance of plant species against pollutants. For example, measurement of physical and chemical characteristics such as cation exchange capacity, electrical conductivity, organic matter, soil reaction. With the help of the statistical analysis, changes in these parameters before and after test period help to determine tolerance of plants [9]. Furthermore, assessment of chlorophyll a fluorescence, photosynthetic pigments and enzymatic activity of superoxide dismutase could be other options for this purpose [10]. Mostly used statistical method after the test and measurements related to plant reaction against pollution is one-way variance analysis (ANOVA). With the help of the ANOVA statistical significance of mean values of different groups may be determined. The main assumption of ANOVA is that independent variables affect dependent variable. Capability of testing the effects of more than one variable is the main advantage of variance analysis [11].

Plant Selection

Plant selection for determining the tolerance could be done with respect to consider previous studies and engineering judgement. Plants which have high biomass production capability are possible to be

used in experiment. Moreover, if the plants are resistant to salty and sodic environment, they could be good candidates for experimental analysis of heavy metal pollution.

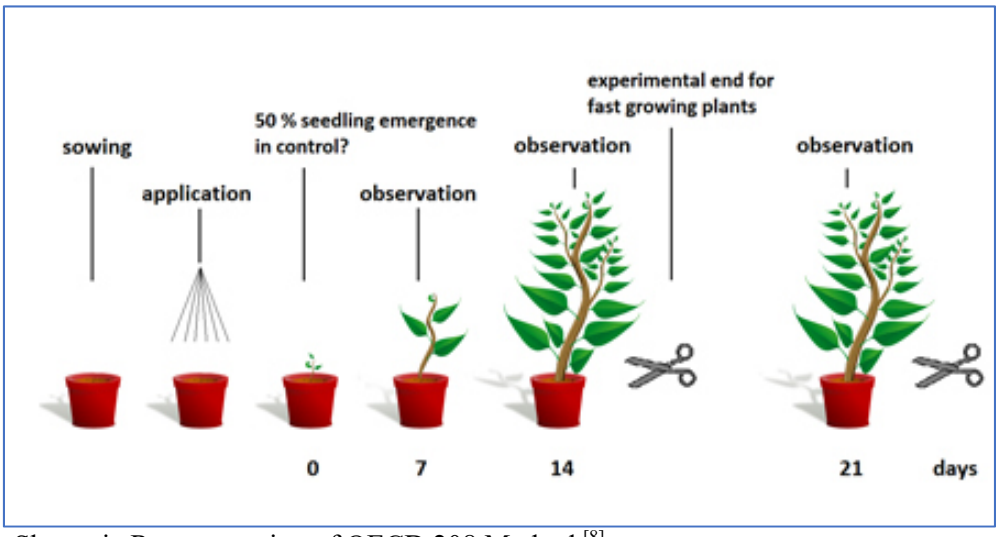

Figure 1. Shematic Representation of OECD 208 Method [8]

RESULTS

Heavy metal accumulation of different plant species is important criteria for usage of them as a bioremediation technique. If their tolerance is high against to the pollutants, they could be used for treating pollution. Industry wastewaters which contain several heavy metals could be source of pollution in several areas. The response of the plants against heavy metals coming from this source gives information about the plants for determine their usage purpose. In Table 1, the plant species which show high tolerance against the heavy metals are given and in Table 2, the plant species which show moderate and low tolerance against the heavy metals are given.

Table 1. The plant species which show high tolerance against the heavy metals

Plant Species	Use of Plant	Heavy Metals	Response
Zea mays L.	Food	Pb, Cd	High tolerance to Cd and Pb pollution [9]
Zea mays L.	Food	Zn, Cu	High tolerance to Cu pollution, poor tolerance to Zn pollution [10]
Brassica sp.	Food	Cd, Pb, Cu, Zn	High tolerance to main heavy metals [12]
Lactuca sativa	Food	Cd, Pb	High tolerance to Cd pollution, moderate tolerance to Pb pollution [13]
Pisum sativum	Food	Cd, Cr, Cu	High tolerance to Cu pollution, moderate tolerance to Cr and Cd pollution [16]
Salvina cucullata	Ornamental	Cd, Cr, Cu, Pb, Zn	High tolerance to Zn pollution, low tolerance to Cd, Cr, Cu, Pb pollution [18]
Trifolium repens	Landscaping	Cd, Pb, Zn	High tolerance to Cd, Pb, Zn pollution [20]

Table 2. The plant species which show moderate and low tolerance against the heavy metals

Plant Species	Use of Plant	Heavy Metals	Response
Lepidium sativum	Food	Hg	Moderate tolerance to Hg pollution, tolerance can be increased with the help of compost and KI. [14]
Lolium perenne	Ornamental	Cu, Pb, Zn	Low tolerance to Cu, Pb, Zn pollution [15]
Spinacia oleracea	Food	Cr, Cd, Zn	Moderate tolerance to Cr, Cd, Zn pollution [19]
Lolium perenne	Ornamental	Cd, Pb, Zn	Low tolerance to Cd, Pb Zn pollution [20]
Solanum lycopersicum	Food	Cd	Low tolerance to Cd pollution [17]

CONCLUSION

Heavy metals originating from industry wastewaters have significant effects especially on human health, plants and animals. Most of them directly affects the quality of the soil, water and air so they should be removed from the wastewaters. Their removal from environment may be provided by several methods such as advanced oxidation, adsorption on new adsorbents, membrane filtration, electrodialysis, and photocatalysis. One of the easiest and cost-effective method is removal of the heavy metals with the help of the plants. Their tolerance against heavy metal contamination of different concentrations prove their ability of bioaccumulation. Within the investigated plant species in this study, high tolerant species against Cu are *Zea mays L.* and *Pisum sativum*, high tolerant species for Pb pollution are *Zea mays L.* and *Trifolium repens*, high tolerant species against Cd pollution are *Zea mays L.*, *Lactuca sativa* and *Trifolium repens*, and high tolerant species against Zn pollution are *Salvina cucullata*, *Trifolium repens*. However, some species show low or moderate tolerance against different heavy metals. They can be used for other purposes. For example, *Spinacia oleracea* and *Solanum lycopersicum* are not effective candidates for Cd pollution but they can be used for treatment purposes when the low concentrations occur. Also, *Lepidium sativum* has moderate tolerance against Hg but it very important because the presence amount of Hg in soil is not so high in mort of the situations. As a result, it is possible to find several plants for bioaccumulation of heavy metals and *Zea mays L.* is the best one which may be used for bioaccumulative removal of Cu, Pb and Cd pollution.

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