*Pol. J. Environ. Stud. Vol. 24, No. 3 (2015), 1423-1426*
DOI: *10.15244/pjoes/26970*

*Short Communication*

# Reducing Heavy Metals Extraction from Contaminated Soils Using Organic and Inorganic Amendments – a Review

**Shazia Gul[1], Alia Naz[1], Iftikhar Fareed[2], Muhammad Irshad[3]***

[1]Department of Environmental Sciences, University of Haripur, Hattar Road Haripur, Pakistan
[2]Department of Natural Resources Engineering and Management, University of Kurdistan, Hewler, Iraq
[3]Department of Environmental Sciences, COMSATS Institute of Information Technology, Abbottabad, Pakistan

*Received: 18 April 2014*
*Accepted: 8 July 2014*

## Abstract

Recently problems relating to environmental pollution and the need to protect and preserve the environment from further deterioration has drawn increasing research attention. The goal of any remediation based on soil amendments is to achieve maximum reduction in the bioavailability of heavy metals by immobilization in soils. Modern remediation approaches increasingly focus on *in situ* environment-friendly techniques. Different organic and inorganic amendments have been used to treat heavy metals-contaminated soils. These included municipal solid waste compost, biosolid compost, cow manure, sheep manure, sewage sludge, bark chips, woodchips, vegetable waste, vermicompost, red mud, lime, beringite, zeolites, charcoal, fly ash; and biochar etc. This review focuses on the effectiveness of soil amendments to reduce toxicity of heavy metals by reducing available fractions that may ultimately reduce the heavy metal transfer to plants.

**Keywords:** heavy metals, contaminated soils, organic material, inorganic material

## Introduction

Heavy metals are released into the environment by both natural and anthropogenic sources. Some soils may have higher levels of heavy metals due to volcanic activity or weathering of parent materials. Anthropogenic activities, including smelting, mining, use of pesticides, fertilizers, sludges, and emissions from industries are also responsible for heavy metals accumulations in the soils. Heavy metals cannot be degraded and hence accumulate in the environment, having the tendency to contaminate the food chain. This pollution threatens soil quality, plant survival, and human health [1].

Metals in the soils can be divided into fractions [2]:

i) Inert fraction, assumed as the nontoxic fraction
ii) The labile fraction, assumed to be potentially toxic

*e-mail: mirshad@ciit.net.pk

To assess the availability of heavy metals, only the soil labile fraction is taken into account because this fraction is often called the bioavailable fraction. However, the bioavailable fraction may be different from other metal fractions. The availability of metals for plants and microorganisms in the soil depends on different constituents of soil such as carbonates, metal hydroxides, organic matter, and silica [2]. The trace elements bioavailability is considered one of the most crucial problems in agricultural and environmental studies [3]. The use of organic and inorganic by-products as soil amendments in agricultural production exemplifies a strategy for converting wastes into resources. The addition of organic matter amendments, such as compost, fertilizers, and farm wastes is a common practice for immobilization of heavy metals and soil amelioration of contaminated soils [4]. Heavy metals-contaminated soil is a global problem. Removal of this persistent pollutant is necessary, but very difficult and costly.

Remediation of heavy metals-contaminated soil with various organic and inorganic amendments has attracted attention due to its low cost and environmental benefits. Studies on the extraction of heavy metal fractions and their bioavailability from contaminated soils using various amendments have often been reported. Therefore, this review compiles earlier reports that focused on the reduction of heavy metals extraction, and their bioavailability or leachability from contaminated soils using organic and inorganic amendments.

## Remediation with Organic Materials

A number of amendments are used either to mobilize or immobilize heavy metals in soils. Different kinds of organic amendments that have been used for the treatment of contaminated soil include manures, biosolids, sawdust, and wood-ash, composts obtained from different source materials, sewage sludge, bark chips, and woodchips. In the case of manure, only composted manure is used for soil treatment purposes as fresh manure can harm plants due to high ammonia levels [5]. A laboratory batch experiment using six potential mineral-organic amendment combinations in the ratio 1:2, (a) composted farmyard manure (cFYM) + gravel sludge (GrS), (b) vemicompost (VC) + GrS, (c) composted sewage sludge (cSS) + GrS, (d) red mud (RM) + cFYM), (e) RM + VC, and (f) cSS + RM were used to treat trace metal-contaminated soil using *Amaranthus viridis* as a test plant. Results showed that all the amendment combinations had different potentials to reduce metal uptake by *Amaranthus viridis* when compared to the control [6].

Cao and Ma [7] used carrot (*Daucus carota* L.) and lettuce (*Lactuca sativa* L.) for their pot experiments, which were grown for 10 weeks in the arsenic-spiked soil with or without compost. This study showed that biosolid compost application (10% w/w) reduced plant uptake of arsenic in carrot by 79-88% and in lettuce by 86-96% as compared to the untreated soil. Arsenic was adsorbed by the organic matter from the compost and the fractionation analysis performed showed a decrease in the amount of water-soluble, exchangeable, and carbonate fractions of arsenic in the soil.

Angelova et al. [4] investigated organic amendments, resulting in an increase in the starch yield, absolute dry substance and quantity, and a decrease of reducing sugars in potatoes. Peat, compost, and vermicompost application led to the effective immobilization of phytoaccessible forms of Pb, Cu, Zn, and Cd in soil. A correlation was found between the quantity of the mobile forms and the uptake of Pb, Zn, Cu, and Cd by the potato. Organic amendments decreased heavy metal contents in potato peel and tubers, and this decrease was best expressed with 10% compost and 10% vermicompost, separately. Organic amendments were especially effective for reduction of Cd content in the potato tubers.

Compost produced from olive leaves and olive mill wastewater and cow manure were used on pyritic (sulphide rich) soil contaminated with Cu 133 $mg\cdot kg^{-1}$, Zn 521 $mg\cdot kg^{-1}$, Pb 220 $mg\cdot kg^{-1}$, and Fe 45713 $mg\cdot kg^{-1}$. The effect of heavy metal bioavailability and vegetation growth were studied in which *Chenopodium album* L. was grown. Air-dried compost and cow manure were added at the rate of 27 and 26 g per kg soil, respectively. The compost amendment to the soil decreased tissue concentrations of Pb, Zn, Fe, and Mn, although Zn and Mn were still toxic. Cow manure reduced shoot concentrations of the heavy metals, especially Zn and Mn, by 91% and 95%, respectively, as compared to the unamended control soils. The cow manure was effective in reducing heavy metal bioavailability, as it increased soil pH and supplied necessary plant nutrients [8]. The use of a variety of composted organic soil amendments (municipal solid waste compost, biosolid compost, mature compost, cow manure, etc.) for restoring heavy metal- and arsenic-contaminated soils [9]. Castaldi et al. [10] studied the effect of a 10% (w/w) amendment of compost produced from olive husks (50%), sewage sludge (25%); and vegetable waste (25%) on soil contaminated with Pb, Cd, and Zn. The amendment resulted in an 87% decrease in the concentration of Pb in the aerial part of the white lupin plant (*Lupinus albus* L.) as compared to the control samples. The concentration of Zn in the aerial part of plants grown in the compost-amended soil was 31% less than the control sample. Application of sheep manure compost (SM compost) was tested by Budai et al. [11] as a possible way for the remediation of polluted soils to produce some special plants. The effects of the SM compost on the growth and stress tolerance of maize (*Zea mays* L.) and Italian ryegrass (*Lolium multiflorum* L.) were investigated. The decrease of heavy metal uptake caused by the compost application was confirmed.

## Remediation with Inorganic Materials

Inorganic amendments also are effective in reducing the metal bio-availability due to the introduction of additional binding sites for heavy metals and due to the pH effects. Many of these amendments are by-products of industrial activities and therefore cheaper and available in large amounts [12]. Different kinds of inorganic materials have been used to decrease heavy metals soil pollution. Among these were biochar, red mud, limestone, etc. Park et al. [13] reported the effect of two biochars in a heavy metal- spiked soil and a naturally polluted soil. Sequential extraction of heavy metals showed that chicken manure biochar was more effective in decreasing extractable concentrations of Cd and Pb, but not Cu. Green waste biochar reduced all the heavy metals. Heavy metal fractions bonded to 20 organic matter increased after biochar addition. Both types of biochars also decreased Cd and Pb in soil pore water [14].

Biochar and phytoremediation techniques have been recently used to target Cd-polluted soils. Uchimiya et al. [15] analyzed the effects on soil heavy metals concentrations of 10 biochars made up from five feedstocks at different temperatures. Manures with a higher or lower proportion of ash or P were less effective at immobilizing heavy metals. In contrast, biochars made at 700ºC were found more effective. This could be attributed to the transformations in the material, including the removal of nitrogen-containing heteroaromatic and leachable aliphatic functional groups. Copper and Pb were relatively immobilized in the soil, while Cd and Ni depended on the type of biochar added to the soil.

Fang and Wong [16] assessed the changes in the water-soluble Cu, Mn, Ni, and Zn concentrations in the sewage sludge co-composted with lime, and reported that water-soluble Pb, Cr, and Cd concentrations in all treatments were significantly reduced. Lime is considered one of the most common and important amendment materials for sewage sludge stabilization as it plays a significant role in reducing the microbial content of sludge, as well as the availability of heavy metals, increasing agricultural profits and lowering the respective environmental risks. Lime has been used for years to increase pH and thus decrease metal uptake by crops. Repeated applications (every 2-5 years; 2-10 $t \cdot ha^{-1}$) is important to maintain metal immobilization and therefore larger quantities are necessary as compared to other inorganic amendments [12]. Oliver et al. [17] observed that Cd concentration in wheat and barley grains can be decreased when pH is increased from 4 to 5 by liming. Liming could reduce the Zn contents in oat grains by 54%.

Bamboo is a renewable bioresource. Bamboo charcoal has a large amount of micropores and an enormously large surface area, about 4 and 10 times higher than those in the wood charcoal, respectively. Bamboo charcoal may be an ideal amendment for nutrient conservation and heavy metal stabilization due to its powerful adsorption capability.

An industrial waste by-product that could be used for remediation of heavy metals is red mud. Red mud is produced during the refining of bauxite to alumina through the Bayer process. It is composed of hematite ($Fe_2O_3$), boehmite (-AlOOH), quartz ($SiO_2$), sodalite ($Na_4Al_3Si_3O_{12}Cl$), and gypsum ($CaSO_4 \cdot 2H_2O$). Red mud addition generally decreases metal leachability and therefore the resultant hazard of releasing metals from sludge compost through adsorption and complexation of the metals on to inorganic components to different extents for the different metals [18]. Qiao and Ho [19] concluded that red mud addition reduces the leachability, plant availability, and total metal concentration. The impact of red mud is different for each metal with a greater effect on Cr, Pb, and Zn speciation than on Cu and Ni speciation.

Zeolites are hydrated aluminosilicates that have selective capabilities to adsorb metals. Therefore, zeolites are considered to be among the most effective mineral amendments decreasing heavy metal transfer to plants. Beside naturally occurring zeolites (clinoptilolite, philipsite, etc.), synthetic zeolites are also promising [12]. Lombi et al. [20] found that the application of red mud, lime, and beringite was very effective at reducing heavy metal uptake of rape, pea, and wheat.

## Conclusions

Different types of organic and inorganic manures are used to treat heavy metals-contaminated soils, including municipal solid waste compost, biosolid compost, cow manure, sheep manure, sewage sludge, bark chips, woodchips, vegetal waste, vermicompost, red mud, lime and beringite, zeolites, charcoal coal, fly ash, biochar. Toxicity of heavy metals does not depend on its total concentration but instead depends on different forms in which metals are present. These amendments can reduce toxicity of metals by reducing available fractions, which in turn reduce heavy metal transfer to plants.

## References


1. FERREIRO P.J., LU H., FU S., MÉNDEZ A., GASCÓ, G. Use of phytoremediation and biochar to remediate heavy metal polluted soils: a review. Solid Earth Discuss. **5**, 2155, **2013**.
2. YOBOUET Y.A., ADOUBY K., TROKOUREY A., YAO B. Cadmium, copper, lead and zinc speciation in contaminated soils. Int. J. Eng. Sci. Tech. **2,** (5), 802, **2010**.
3. GUPTA A.K., SINHA S. Phytoextraction capacity of the plants growing on tannery sludge dumping sites. Bioresource Technol. **98**, 1788, **2007**.
4. ANGELOVA V., IVANOV R., PEVICHAROVA G., IVANOV K. Effect of organic amendments on heavy metals uptake by potato plants. 19th World Congress of Soil Science, Soil Solutions for a Changing World Brisbane, Australia. Published on DVD, **2010**.
5. DAVIS J.G., WILSON C.R. Colorado State University Cooperative Extension-Horticulture. Bulletin number **7**, 235, **2005**.
6. NWOKO C.O., ONOH C.P., ONOH G.O. Remediation of trace metal contaminated auto-mechanic soils with mineral supplemented organic amendments. Univ. J. Environ. Res. Tech. **2,** (6), 489, **2002**.
7. CAO X., MA L.Q. Effects of compost and phosphate on arsenic accumulation from soils near pressure-treated wood. Environ. Pollut. **132**, 435, **2004**.
8. WALKER D.J., CLEMENTE R., BERNAL M.P. Contrasting effects of manure and compost on soil pH, heavy metal availability and growth of *Chenopodium album* L. in a soil contaminated by pyritic mine waste. Chemosphere. **57**, 215, **2004**.
9. GADEPALLE V.P., OUKI S.K., HERWIJNEN R.E.V., HUTCHINGS T. Immobilization of heavy metals in soil using natural and waste materials for vegetation establishment on contaminated sites. Soil Sed. Contam. **16**, 233, **2007**.
10. CASTALDI P., SANTONA L., MELIS P. Heavy metal immobilisation by chemical amendments in a polluted soil and influence on the white lupin growth. Chemosphere. **60**, 365, **2005**.
11. BUDAI J., ANTA K., BLASCO L. Possibility of remediation of a heavy metal polluted soil. Analele Universităţii din Oradea, Fascicula:Protecţia Mediului XIV, **2009**.
12. PUSCHENREITER M., HORAK O., FRIES W., HART W. Low-cost agricultural measures to reduce heavy metal transfer into the food chain- A review. Plant Soil Environ. **51**, 1, **2005**.
13. PARK J.H., CHOPPALA G.H., BOLAN N.S., CHUNG J.W., CHUASAVATHI T. Biochar reduces the bio-availability and phytotoxicity of heavy metals. Plant Soil **348**, 439, **2011**.
14. LEHMANN J., RILLIG M.C., THIES J., MASIELLO C.A., HOCKADAY W.C., CROWLEY, D. Biochar effects on soil biota, A review. Soil Biol. Biochem. **43**, 1812, **2011**.

15. UCHIMIYA M., CANTRELL K.B., HUNT P.G., NOVAK J.M., CHANG S.C. Retention of heavy metals in a Typic Kandiudult amended with different manure-based biochars. J. Environ. Qual. **41**, 1138, **2012**.
16. FANG M., WONG J.W.C. Effects of lime amendment on availability of heavy metals and maturation in sewage sludge composting. Environ. Pollut. **106**, 83, **1999**.
17. OLIVER D.P., TILLER K.G., CONYERS K.M., SLATTERY W.J., ALSTON A.M., MERRY R.H. Effectiveness of liming to minimize uptake of cadmium by wheat and barley grain grown in the field. Aust. J. Agric. Res. **47**, 1181, **1996**.
18. SINGH J., KALAMDHAD A.S. Reduction of heavy metals during composting – A review. Int. J. Environ. Protect. **2,** (9), 36, **2012**.
19. QIAO L., HO G. The effects of clay amendment and composting on metal speciation in digested sludge. Water Res. **31,** (5), 951, **1997**.
20. LOMBI E., ZHAO F.J., WIESHAMMER G., ZHANG G., MCGRATH S.P. *In situ* fixation of metals in soil using bauxite residue: biological effects. Environ. Pollut. **118**, 445, **2002**.