Moringa oleifera: A new challenge reducing heavy metal toxicity: A review

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ABSTRACT

Various parts of Moringa oleifera i.e., fruit, seed, leave, flower, bark, and root, have been used extensively in traditional medicine. One of these usages is the reducing of heavy metal toxicity. The mechanism of metal removal property by using the characteristic of its surface morphology and functional groups to uptake the heavy metal. Moreover this plant reduced the metal toxicity in living organism by its antioxidant properties. The advantage utilization of this plant is very interesting as it can easily be cultivated worldwide. Its biosorbent properties are inexpensive, availability, profitability easy of operation, effectiveness in reducing the concentration of heavy metal ions to very low levels. Besides, this plant is reported to have various chemical constituents that have the biological activities including the depletion of metal concentration and the antioxidant properties that are potential to reduce the oxidative stress induced by heavy metal.

Key words: Adsorption, Antioxidant, Heavy metal, Moringa oleifera, Traditional medicine.

INTRODUCTION

Nowadays, heavy metal is currently the serious pollution problem and increasingly prevalent in our daily life which should never be neglected. It has been identified in the polluted environment include cationic metals i.e., cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), zinc (Zn) whereas anionic metals are arsenic (As), boron (B), molybdenum (Mo), selenium (Se) (USDA, 2000). Natural as well as anthropogenic actions are the hundred sources of heavy metal pollution include point sources such as emission, effluent, smelting, mining, discharge from industry, vehicle exhaustion. The non-point sources are use of pesticide and municipal waste in agriculture, disposal of industry (Lone et al. 2008). Arsenic is used as semiconductor, animal feed additive, herbicides and wood preservative (Kumari et al., 2006). Copper is used as electroplating, smelting and refining (Rai and Pal, 2002). Cadmium is used as color pigment, and rechargeable battery (Ivanova et al., 2013). Chromium is used as metal alloy, color pigment, cement, rubber industry, paper and pulp mill (Akunna et al., 2012). Lead is used as building material, paint and antiknock in petrol (Reddy et al., 2010). Mercury is used as a whitening cosmetic, syphilis treatment and filling teeth (Jarup, 2003). Nickel is used as electroplating, stainless steel, ceramic and aircraft industry (Reddy et al., 2011). The epidemiological studies of heavy metal poisoning were reported i.e., the chronic cadmium intoxication or itai-itai disease in Japan in 1947 caused a yellow discoloration of teeth or cadmium ring, lost of the sense of smell, dry mouth, anemia and impairment of bone marrow (Inaba et al., 2005). The most obvious sign after exposure with arsenic was the blisters on the palms and soles, which could eventually turn gangrenous and cancerous as known as the black foot disease. The four serious incidents of arsenic outbreaks had been reported in People’s Republic of China (Lian and Jian, 1994), India (Mandal et al., 1999), Bangladesh (Smith et al., 2000) and Taiwan (Yang et al., 2003). The Minamata disease was follow by the outbreak of mercury poisoning in 1956 because people who living around Minamata bay in Japan after consumed fish and progressively suffered from a weakening of muscles, loss of vision, impairment of cerebral function (Yorifuji et al., 2011). In 1960 fatal incidents of lung cancer were reported from Japan due to inhalation of dust containing chromium (Rai and Pal, 2002). The US Environmental Protection Agency suggests that cadmium, copper, lead, manganese, nickel and zinc in drinking water should not exceed 0.005, 1.3, 0.015, 0.05, 0.04 and 5 mg L⁻¹, respectively (USDA, 2000; Obuseng et al., 2012).

The traditional methods used for the removal of heavy metal from the wastewater are filtration (Sun et al., 2009), chemical precipitation (Fu et al., 2012), ion exchange (Lee et al., 2007), reverse osmosis (Mohsen-Nia et al., 2007), and adsorption (Kita and Skoblewski, 2010). The use of plant species for cleaning polluted soil and water named as phytoremediation, has gained increasing popularity due to the more cost-effective and fewer side effects than physical and chemical approaches (Ali et al., 2013). Numerous plant species have been identified and examined for their potential in reducing different heavy metal toxicity. Among them, Moringa oleifera, is the new challenge of tradition medical...
plant use both *in vitro* and *in vivo* for reducing metal toxic in environment and living organism.

**Moringa oleifera:** *M. oleifera* is known by such regional names as (Africa) mrongo, mzunze, (Bangladesh) sjina, (Cambodia) ben aile, daem mrum, (China) la mu, lat mok, la ken, (Colombia) angela, (France) moringe à graine aillée, (Ghana) yevu-ti, zigerindende, (India) segra, shajmah, sigru, (Indonesia) kalor, kelor, (Kenya) mronge, (Myanmar) daintha, dandalun, (Nepal) shobhanjan, sitachini, (Nigeria) ewe ile, bagaruarwa maka, (Pakistan) soanjana, suhanjna, (Philippines) mulangai, mulangay, (Spain) árbol del ben, ángela, (Sri Lanka) murunga, (Taiwan) la mu, (Thailand) marum, (Vietnam) chum ngay, (Zimbabwe) mupulanga (Fahey, 2005; Parrotta, 2009; Paliwal *et al.*, 2011). The other common names are from the appearance of the long, slender pod which calls drumstick tree, from the spicy taste which calls horseradish tree or from the seed oil extract which calls benzoil tree (Paliwal *et al.*, 2011). *M. oleifera* is the most widely known in family of Moringaceae which has 13 species, *M. arborea*, *M. borziana*, *M. concanesis*, *M. drouhardii*, *M. hildebrandtii*, *M. longituba*, *M. oleifera*, *M. ovalifolia*, *M. peregrina*, *M. pygmaea*, *M. rivae*, *M. ruspoliana*, and *M. stenopetala* (Mahmood *et al.*, 2010; Paliwal *et al.*, 2011). The taxonomy of *M. oleifera* is in the Kingdom (Plantae); Subkingdom (Tracheobionta); Superdivision (Spermatophyta); Division (Magnoliophyta); Class (Magnoliopsida); Subclass (Dilieniidae); Order (Brassicales); Family (Moringaceae); Genus (Moringa); Species (*Moringa oleifera*) (USDA, 2013). The moringa tree is a small to medium size shrub, evergreen or deciduous tree common throughout the semi-arid tropical and subtropical regions of Africa, South America and Southeast Asia since its preferred dry, sandy soil habitat (Fig 1). It characterizes as fast rate growth and can be as tall as 7-12 m. and as wide

![pod](image1.png)

![leaves](image2.png)

![seeds](image3.png)

![flowers](image4.png)

**Moringa oleifera**

**FIG 1:** The general morphology of *Moringa oleifera*
as 20-40 cm. The stem is straight with a whitish-grey color, thick, soft, fissured and warty or corky, is easily peel off. The flower has pleasant fragrance and is 2-5 cm wide producing profusely in auxiliary drooping panicles of 10-25 cm long. It is white or cream color and yellow dotted at the base. The fruit is pendulous, linear, three-sided pods with nine longitudinal ridges, usually 20-60 cm long and 2.0-2.5 cm broad, containing 12-35 black seeds. The seed is about 1 cm in diameter, round shape, dark brownish with three whitish papery wings on the angles. The alternate, pinnate leaves grow mostly at the branch tips; they are 1.2 to 2.0 cm long and 0.6 to 1.0 cm wide. The leaflets are finely hairy, green and almost hairless on the upper surface, pulper and hairless beneath, with red-tinged mid-veins, and are rounded or blunt-pointed at the apex and short-pointed at the base (Figure 1, Fahey, 2005; Parrotta, 2009).

**In vitro reducing metal toxicity:** Several researches have focused on the use of various parts of *M. oleifera* in water purification and the treatment of turbid water is the best-known application (Pritchard et al., 2010; Nkurunziza et al., 2009). The seed contains cationic polyelectrolytes which have proved to be effective in the treatment of water, as a substitute for aluminum sulfate. Interesting in the study of natural coagulants for water contaminated with heavy metal is new and many studies have been performed in order to explore this application (Araújo et al., 2013; Obuseng et al., 2012). For removal of arsenic (Kumari et al. 2006), cadmium (Sharma et al., 2006), chromium (Sharma et al., 2007), lead (Reddy et al., 2010), copper (Kalavathy & Miranda 2012), nickel (Marques et al., 2012; Reddy et al., 2011), silver (Araújo et al., 2010), and zinc (Bhatti et al., 2007) were reported by used several parts of *M. oleifera* plant.

Numerous studies have shown that *M. oleifera* possess effective coagulation properties. Ndabigengesere et al. (1995) reported that under non-reducing conditions, the coagulant proteins from *M. oleifera* seeds are 13 kDa dimeric cationic proteins with an isoelectric point pH 10-11, but under reducing conditions, the molecular weight was found to be 6.5 kDa. They suggested that the active protein is actually composed of two 6.5 kDa subunits, connected with an S-S bond that is cleaved when protein extraction occurs in reducing conditions, and that the mechanism of coagulation with *M. oleifera* consist of adsorption and charge neutralization of the colloidal charges. Agree with Gassenschmidt et al. (1995) who reported that the isolation from *M. oleifera* of a flocculating protein with the same molecular mass 6.5 kDa, isoelectric point above pH 10, high levels of glutamine, arginine and proline with the amino terminus blocked by pyroglutamate, and flocculant capacity comparable to a synthetic polyacrylamide cationic polymer. Scanning electron microscope has been widely used to study the morphological features of the biosorbent. *M. oleifera* bark India plant, showed the presence of asymmetric pores and open pore structure, which may provide high internal surface area and a rough structure on the surface bark, which is favorable for biosorption of heavy metal from aqueous pollutions (Reddy et al., 2011). The X-ray diffraction pattern of *M. oleifera* bark showed the presence of an amount of amorphous material due to lignin and tannin. The Fourier transform infrared spectra of *M. oleifera* bark showed the presence of many functional groups, including hydroxyl group, carboxylic acid and carbonyl group (Reddy et al., 2011). The change in hydroxyl group after biosorption indicated that it had been changed from multimer to monomer or even dissociative state which showed that the degree of hydroxyl polymerization in lignocellulose was decreased by binding of nickel. These indicated that the biosorption of metal occurs at hydroxyl, carboxyl and carbonyl functional groups present on the surface of the plant (Reddy et al., 2011). The similar results were reported in the biosorption of lead by leave (Reddy et al., 2010), arsenic by seed (Kumari et al., 2006), cadmium by seed (Sharma et al., 2006), copper, nickel and zinc by bark (Kalavathy and Miranda, 2012) using electron microscope, fourier transform infrared spectrophotometer, wide angle X-ray diffraction.

Obuseng et al. (2012) reported that the carboxylic acid and hydroxyl groups presented *M. oleifera* play a major role in the removal of heavy metal ions as observed from the significant reduction in the intensity or shift in their intensity peaks for metal-loaded by using fourier transform infrared spectrophotometer. They also reported that the trend of heavy metal removal using sonication method followed the order: Pb > Cu > Cd > Ni > Mn. Similarly results reported by Ravikumar and Sheeja (2013) that the percentage removals by *M. oleifera* seed India plant were Cu(95%) > Pb(93%) > Cd(76%) > Cr(70%). Sharma et al. (2007) also reported that the percentage removals by *M. oleifera* seed India plant were Cd(85%) > Cr(81%) > Ni(76%).

Biosorption can be defined as the ability of biological materials binding with heavy metal from wastewater. The active agents in this plant are glucosinolates and phenolics which are the functional groups that are capable of anchoring metals (Bennett et al., 2003). Biosorption activity could be explained by the charge-patch mechanism due to low molecular weight and high charge density.

**In vivo reducing metal toxicity:** The researches that regarding treatment of heavy metal are restricted mainly to some chelating agents or in combination with few antioxidants but most of the conventional metal chelating agents and antioxidants have been reported to possess toxic side effects or disadvantages i.e., headache, nausea, hypertension, hepatotoxicity, and nephrotoxicity (Flora, 2009; Ivanova et al., 2013). The properties of chelating agents are capable of binding to toxic metal ions to form
complex structures which are easily excreted from the body removing them from intracellular or extracellular spaces (Flora and Pachauri, 2010). Newer strategy in the therapeutic potential of medicinal plant or herb in reducing metal toxicity is increased interested. *M. oleifera* is reported to have various biological activity, including hypolipidemia (Ghasi *et al.*, 2000), regulation of thyroid hormone (Tahilian and Kar, 2000), antihyperglycemia (Jaiswal *et al.*, 2013), antibacterial properties (Horwath and Benin, 2011), antiulcer (Choudhary *et al.*, 2013), antitumor (Sreelatha *et al.*, 2012), and antinflammation (Alhakmani *et al.*, 2013), cardioprotective (Panda *et al.*, 2013), hepatoprotective (Hamza, 2010), nephroprotective (Ouedraogo *et al.*, 2013) and neuroprotective activity (Bakre *et al.*, 2013). This article reviewed the new challenge of *M. oleifera* in relation to the treatment of heavy metal toxicity in environment and living organism.

Grabow *et al.* (1985) reported that the therapeutic efficacy of oral administration of 500 mg kg⁻¹ is not toxic to human or to animal. After exposure the 100 ppm sodium arsenate in drinking water for 120 days, the therapeutic dose of seed power of *M. oleifera* India plant was fed to rat. In the blood of arsenic treated rat showed decrease of d-aminolevulinic acid dehydratrase (ALAD) activity, reduced glutathione (GSH) level but increase in reactive oxygen species (ROS) in blood. In the liver was also found decrease in ALAD, but increase in d-aminolevulinic acid synthetase (ALAS) and thiobarbituric acid reactive substances (TBARS). Activities of liver, kidney and brain superoxide dismutase (SOD) and catalase also showed a decrease on arsenic exposure. Administration of *M. oleifera* seed powder post arsenic exposure, exhibited recovery in blood ALAD activity, it restored blood GSH and ROS levels. A protection in the altered ALAD and ALAS activities of liver and TBARS level was also observed. The plant is help to deplete the amount of arsenic from blood, liver and kidneys (Gupta *et al.*, 2005).

After exposure the 150 ppm potassium dichromate in drinking water for 100 days, the 50 mg kg⁻¹ of leave power of *M. oleifera* Nigeria plant was fed to rat. The chromium treated rat showed a decrease in body weight, testis weight, testis volume, testis weight/body weight ratio, plasma testosterone level, testicular enzyme glutathione peroxidase, sperm parameters i.e., sperm morphology, motility, concentration. But the treatment with moringa plant slightly prevented the chromium toxicity by enhancing the testicular morphology, improve sperm parameters, and also testosterone level (Akunna *et al.*, 2012).

The fish were fed with the supplementation with 60 mg g⁻¹ fish food of leave power of *M. oleifera* Thailand plant for 28 days, and then exposed with 50% of 24h-LC₉₀ of lead nitrate for 24 hours. In the non pre-moringa fed group, after lead-exposure, fish showing loss of normal gill architecture, primary and secondary lamellar disorganization, abnormal regeneration of epithelial cells, filament epithelium hyperplasia, aneurysms and lifting of the outer layer of the lamellae epithelium with the space under the epithelium. The liver was shown abundant cytoplasmatic vacuolation, some hepatocytes showing hypertrophy nuclei, and parenchyma disorganization. Renal tissue was shown glomerulus atrophy, increase number of lymphocytes in parenchyma, cloudy swelling, tubular narrowing and hyaline droplet. In contrast, the pre-moringa fed group showing slightly histopahtological change in gill, liver, and kidney. Moreover it was found numerous of mucous cells per lamella with histochemical technique (Sirimongkolvorakul *et al.*, 2012; 2013).

**Chemical composition and antioxidant:** Various parts of *M. oleifera* have been analyzed for chemical constituents. It is found that glucosinolates and phenolics (flavonoids, anthocyanins, proanthocyanidins, and cinnamates) are the major compounds (Araújo *et al.*, 2013). *M. oleifera* seed is reportedly containing 4-(α-L-rhamnopyranosyloxy)-benzylglucosinolates (Bennett *et al.*, 2003) and also has proanthocyanidin and flavonoid content (Compahoe *et al.*, 2011). The root has high concentrations of both 4-(α-L-rhamnopyranosyloxy)-benzylglucosinolate and benzyl glucosinolate (Bennett *et al.*, 2003). The leaf contain 4-(α-L-rhamnopyranosyloxy)-benzylglucosinolate and three monoacetyl isomers of this glucosinolate (Bennett *et al.*, 2003). The major phytochemical constituents in the leaves are phenolic compounds and flavonoids including quercetin and kaempferol (Verma *et al.*, 2009; Vongsak *et al.*, 2013). The bark contain only 4-(α-L-rhamnopyranosyloxy)-benzylglucosinolate (Bennett *et al.*, 2003). Phytochemical analysis revealed the presence of tannins, flavonoids, steroids and alkaloids in the bark (Kumbhare *et al.*, 2012). The chemical compositions in this plant have more powerful antioxidants which are the advantage product to reduce the heavy metal toxicity.

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