

PHYTOREMEDIATION BEHAVIOUR of SOME MEDICINAL and AROMATIC PLANTS to VARIOUS POLLUTANTS

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ABSTRACT

Medicinal and aromatic plants have been used as herbal remedies and affordable health care products worldwide. Currently, their importance in conservation of vital biodiversity is detected and researches on this subject gained ground. Environmental contamination by heavy metals such as mercury, cadmium and lead is a serious problem throughout the world. Heavy or toxic metals are trace metals that are at least five times denser than water. They are also stable elements and can not be metabolized by the body or bio-accumulative and they passed up the food chain to humans. Toxic industrial wastes mixing with liquid agricultural fertilizers disperse farmlands. Reclamation of agricultural soil and transition of the metal ions into insoluble forms may quite expensive and can hardly be applied to huge areas. Heavy metal accumulator plants can be used as alternative solution for solving the problem. Researches on certain medicinal and aromatic plants (mint, lavender, thyme, st. john's wort, pot marigold, hollyhock, garden sorrel, black nightshade sp. etc) showed that they can be more resistant to some heavy metals and other pollutants than other crops.

Key Words: Medicinal and aromatic plants, pollutants, phytoremediation

BAZI TIBBİ VE AROMATİK BİTKİLERİN FARKLI KİRLİLİK ETMENLERİNE KARŞI FİTOREMEDİASYON DAVRANIŞLARI

ÖZET

Tıbbi ve aromatik bitkiler koruyucu ve tedavi edici olarak kullanılmaktadır. Son zamanlarda, biyolojik çeşitliliğin korunması ve gelecek kuşaklara aktarılmasında önem kazanmışlardır. Civa, kadmiyum ve kurşun gibi ağır metallerin neden olduğu çevre kirliliği tüm dünyayı tehdit eder hale gelmiştir. Ağır ya da toksik metaller sudan beş kat daha yoğun ve hareketsiz olduklarından vücut tarafından sindirilemezler ancak besin zincirine geçebilirler. Zehirli endüstriyel atıklar sıvı gübrelere karışarak tarım arazilerine yayılabilmektedirler. Topraktaki metal iyonların çözünemeyen formlara dönüştürülmesi oldukça pahalı, geniş alanlara uygulanabilirliği de oldukça zor görünmektedir. Ağır metalleri bünyelerinde toplayan bitkiler sorunun çözümünde alternatif olarak görünmektedirler. Yapılan araştırmalar çeşitli tıbbi ve aromatik bitkilerin (nane, lavanta, kekik, kantaron, kenevir, portakal nergisi, gül hatmi, labada, it üzümü vs) ağır metal ve çeşitli kirlilik etmenlerine aynı şartlarda yetiştirilen diğer bazı kültür bitkilerine kıyasla çok daha dayanıklı olduklarını göstermiştir.

Anahtar kelimeler: Tıbbi ve aromatik bitkiler, çevre kirleticiler, fitoremediasyon

1. INTRODUCTION

Some metals are naturally found in the body and are essential to human health (iron, zinc, magnesium and copper), however, most of the heavy metals such as mercury, nickel, lead, arsenic, cadmium, aluminium, platinum, and copper (metallic form versus ionic form) act as poisonous and interference to the enzyme systems and metabolism of the body. On the other hand, some types of metal such as Cu, Mn and Zn are the natural essential components of coenzymes and they are important for growing, photosynthesis and respiration (Sovljanski *et al.* 1989).

Environmental contamination with heavy metals is a serious growing problem throughout the world. In today's industrial society, there is no way to avoid the exposure to toxic chemicals and metals. Heavy metals are enriched in the environment by human activities of different kinds (Dean *et al.* 1972). Results of these activities end up in outlets and wastes where they are transported to the environment by air, water or deposits, thereby increasing the metal concentrations in the environment (Greger 2004). In general, heavy metals (HM) are systemic toxins with specific *neurotoxic*, *nephrotoxic*, *fetotoxic* and *teratogenic* effects (Nordberg 1999). HM can directly affect on human behaviour by impairing mental and neurological functions and they can cross the placental barrier, and they can be found in breast milk, intellect and the developing nervous system in children (Tong *et al.* 2000, WHO, 2003). From plant nutrition studies, it is known that plants require a certain amount of trace elements that they respond differently to an enhanced or lowered trace element supply, and that, in some cases agricultural products may be contaminated with toxic heavy metals (Krug, 1986).

Bioremediation has gained a lot of importance recently as an alternate technology for removal of elemental pollutants in soil and water, which require effective methods of decontamination. Phytoremediation; the use of green plants to remove, contain or render harmless environmental pollutants, may offer an effective, environmentally non destructive and cheap remediation method. Remediation of HM contaminated sites using hyperaccumulators also presents a promising alternative to current environmental methodologies (Eapen and D' Souza, 2005). The aim of this article is to review, the response of medicinal and aromatic plants to heavy metals and their roles in phytoremediation as hyper accumulators.

2. HEAVY METAL ACCUMULATION IN SOME MEDICINAL PLANTS

Heavy metal is the generic name given to the group of elements with an atomic density greater than 6 g cm^{-3} . While these elements are ubiquitous in the Earth's crust, their concentration and availability in soil and water varies from less than 1000 parts per million ($\text{ppm} = \text{mg kg}^{-1} = \text{mg L}^{-1}$) to a few parts per billion ($\text{ppb} = \mu\text{g kg}^{-1} = \mu\text{g L}^{-1}$), with the exception of manganese, which is found in soils in concentrations ranging from 20 to 10,000 ppm (Alloway 1995).

Heavy metal contents in spices and medicinal plants depend on climatic factors, plant species, air pollution and other environmental factors (Sovljanski *et al.* 1989). Medicinal plants may carry residuals of environmentally persistent pesticides or assimilate heavy metals in

varying degrees. Several factors may influence accumulation of contaminants, including species, level and duration of exposure to contaminant, and topography. There are some researches reported from different areas which were conducted to search of the accumulation certain medicinal plants.

Khan *et al.* (2001) analyzed 21 over-the-counter ginseng (*Panax ginseng*) products in various dosage forms. In the study Cr, Mg, and Ar were undetectable above their limits of detection in both liquid and solid samples; while Cd, Pb, and Ni were present in the majority of samples. The chlorinated pesticide levels varied widely. In most samples, the total concentration of pesticides was below 100 ppb; while in 5 samples the total concentration exceeded 100 ppb.

The research on 'the heavy metal in Egyptian spices and medicinal plants and the effect of processing on their levels' was conducted by Arab and Donia (2000). They showed that 20 different types of spices and medicinal plants with different growing seasons and each with its own agricultural practises, collected from different sources of exportation in Egypt were tested. They recorded the highest Sn and Mn levels from the tea samples (0.1 and 343 $\mu\text{g g}^{-1}$ respectively), Ni and Zn from the (2.85 and 35.5 $\mu\text{g g}^{-1}$ respectively) basil and Pb (14.4 $\mu\text{g g}^{-1}$) from marjoram. The results also proved that celery, parsley, and spearmint contained the highest mean levels of Cd (2.44 $\mu\text{g g}^{-1}$), Cu (11 $\mu\text{g g}^{-1}$) and Fe (1046 $\mu\text{g g}^{-1}$). It was observed that the lowest mean levels of Pb, Cd, Ni, Sn and Mn were detected in Jew's Mallow with 1.14, 1.06, 0.61, 0.01 and 22.4 $\mu\text{g g}^{-1}$ respectively. The lowest mean levels of Zn (8 $\mu\text{g g}^{-1}$), Cu (1.8 $\mu\text{g g}^{-1}$) and Fe (145 $\mu\text{g g}^{-1}$) were scored in tea.

St. John's wort, (*Hypericum perforatum* L.) is one of the most important medicinal plants used for centuries, as anti-depressive agents (Verotta 2003; Kim *et al.* 1999; Müller *et al.* 1999). Recent studies have shown that St. John's wort can accumulate higher contents of Cd than other plants grown under the same conditions (Malko 2002; Schneider and Marquard 1995; 1996 b). *Hypericum* sp. accumulates high Cd concentrations in the shoots without negative effect on the growth and dry matter production. Because higher Cd concentrations can be found in the plant than in the soil, they are characterised as Cd accumulators (Masarovicova *et al.* 2004; Baker 1981; Schneider and Marquard 1995, 1996 a,b). Field crops, by means of their larger shoots and rooting systems, may accumulate available Cd easily from the soil than that of the *H. perforatum* in the natural vegetation (Chizzola and Lukas 2005). In another experiment, Tirillini *et al.* (2006) worked on the response of *H. perforatum* seedlings' to chromium added media. They found that Hypericin (the main component of the essential oil) was not affected from chromium.

A growth room experiment was conducted to evaluate the bioavailability of Cu, Mn, Zn, Ca, Fe, K, Mg, P, S, As, B, Cd, Co, Cr, Hg, Mo, Na, Ni, Pb, and Se from a sandy loam soil amended with source-separated municipal solid waste (SSMSW) compost. Basil (*Ocimum basilicum* L.) and Swiss chard (*Beta vulgaris* L. cv. Fordhook Giant) were amended with 0, 20, 40, and 60% SSMSW compost to soil (by volume) mixture. Soils and compost were sequentially extracted to fractionate Cu, Pb, and Zn into exchangeable (EXCH), iron- and manganese-oxide-bound (FeMnOX), organic-matter (OM), and structurally bound (SB) forms. Overall, in both species, the proportion of Cu, Pb, and Zn levels in different fractions followed the sequence: SB > OM >> FeMnOX > EXCH for Cu; FeMnOX = SB > OM > EXCH for Pb; and FeMnOX > SB = EXCH >> OM for Zn. Application of SSMSW compost increased soil

pH and electrical conductivity (EC), and increased the concentration of Cu, Pb, and Zn in all fractions, but not EXCH Pb. Basil yields were highest in the 20% treatment, but Swiss chard yields were higher in all compost-amended soils than those of the un-amended soil. Basil plants in 20 or 40% compost treatments reached flowering earlier than plants from other treatments. Additions of SSMSW compost to soil altered basil essential oil, but basil oil was free of metals. The results obtained from the study suggested that mature SSMSW compost with concentrations of Cu, Pb, Mo, and Zn of 311, 223, 17, and 767 mg kg⁻¹, respectively, could be used as a soil conditioner without phytotoxic effects on basil and sugar beet and without increasing the normal range of Cu, Pb, and Zn in crop tissue. However, the long-term effect of the accumulation of heavy metals in soils needs to be carefully considered (Valtcho and Philip 2003).

3. THE ROLE OF MEDICINAL PLANTS IN PHYTOREMEDIATION

Phytoremediation is the use of certain plants to clean up soil, sediment, and water contaminated with metals or organic contaminants such as crude oil, solvents, and polyaromatic hydrocarbons (PAHs). It is a name for the expansion of an old process that occurs naturally in ecosystems as both inorganic and organic constituents cycle through plants. Plant physiology, agronomy, microbiology, hydrogeology, and engineering are combined to select the proper plant and conditions for a specific site. Phytoremediation is an aesthetically pleasing mechanism that can reduce remedial costs, restore habitat, and clean up contamination in place rather than entombing it in place or transporting the problem to another site (Zynda 2001).

The amounts of aerosol particles could be sharply decreased by improving the technology used in the smelter, or by using better filters for the stacks. However, the soil is already highly polluted with heavy metals. Even there are several chemical and physical approaches for cleaning the soils or for transition of the metal ions into insoluble forms, all of them are quite expensive and they can hardly be applied to thousands of hectares. Finding some heavy metal tolerant crops whose final products are not contaminated could be one alternative to solve the problem. Zheljzkov and Nielsen (1996) worked on the effect of heavy metals on peppermint and corn mint in the area suffering from pollution in Bulgaria. Pollutants were some non-ferrous metal smelters, such as the Non-Ferrous Metals Combine (NFMC) near Plovdiv, situated on very fertile soils (Sengalevitch 1993). Although mint could be grown as a 2-3 years crop, they conducted the experiment annually to minimize the effect of heavy metals on the growth and productivity of mint plants (Davies 1993). At a distance of 400 m from the source of pollution the fresh yields decreased as an average of 9-16% in all samples. In the contrary, at the same distance from the smelter they didn't record any yield reduction in lavender. Essential oil contents in fresh herbage weren't affected by the level, of heavy metal pollution, conforming data from lavender (Zheljzkov and Nielsen 1993). However, due to the decreasing herbage yield essential oil yield from plot 1 also decreased by up to 14%. It was concluded that the tested cultivars of peppermint and corn mint could be successfully grown in highly heavy metal polluted areas, as in the area around NFMC near Plovdiv, without contamination of the end product – the essential oils. Despite yield reduction (up to 14%), due

to heavy metal contamination, mint still remained a very profitable crop and it could be used as substitute for the other highly contaminated crops.

Cannabis sativa is an annual herb with very high biomass and capability to absorb and accumulate heavy metals in roots and shoots; it is, therefore, a good candidate for phytoremediation of soils contaminated with metals. Copper is an essential micronutrient for all living organisms, it participates as an important redox component in cellular electron transport chains; but is extremely toxic to plants at high concentrations. Copper stress induced the suppression of two proteins, the down-regulation of seven proteins, while five proteins were up-regulated. The resulting differences in protein expression pattern were indicative of a plant adaptation to chronic stress and were directed to the reestablishment of the cellular and redox homeostasis (Bona et al. 2007).

Wang et al. (2003) investigated heavy metal contamination in soils and plants at polluted sites in China including some with heavy industries, metal mining, smelting and untreated wastewater irrigation areas. Substantial differences in the accumulation of heavy metals were observed among the plant species under investigation. *Polygonum hydropiper* growing on contaminated soils in a sewage pond had accumulated 1061 mg kg^{-1} of Zn in its shoots. *Rumex acetosa* L. growing near a smelter accumulated more than 900 mg kg^{-1} of Zn both in its shoots and roots. Therefore, these species showed the potential for phytoremediation of metal-contaminated sites. Another research conducted by Jeliaskova et al., (2003) indicated that caraway could be potentially used for phytoremediation of soil contaminated with Cd+Pb, if the metals concentration in the soil solution did not exceed 6 mg/l.

The effect of Fe was investigated in medicinally important plant, (*Bacopa monnieri* L.) and the response on malon-di-aldehyde (MDA) content, super oxide dismutase (SOD), peroxides (POD) and ascorbate peroxides (APX) were found to be varying in roots and leaves of the metal treated plants. Iron induced stress was observed due to the high level of lipid peroxidation, this increased in leaves more than roots. In roots, SOD activity was found to increase in metal treated plants except 80 and $160 \mu\text{M}$ at 72 h, whereas, except 10 and $40 \mu\text{M}$ after 48 h versus controls SOD activity decreased in leaves. The coefficient correlation was evaluated for the metal accumulations versus various parameters and also for different antioxidant parameters versus MDA. Since the level of bacoside-A (active constituent) content in metal treated plants increases, therefore, it is advisable to assess the biological activity of the plants before the use for medicinal purposes, particularly in developing countries (Sinha and Saxena 2006).

Jiang et al. (2001) searched cadmium chloride concentration on root, bulb and shoot growth of garlic (*Allium sativum* L.), the uptake and accumulation of Cd^{+2} by garlic roots, bulbs and shoots were also investigated. Garlic has considerable ability to remove Cd from solutions and accumulate it. The Cd content in roots of garlic increased with increasing solution concentration of Cd^{+2} . The roots in plants exposed to 10^{-2} M Cd accumulated a large amount of Cd approximately 1,826 times the control. The Cd contents in roots of plants treated with 10^{-3} , 10^{-4} , 10^{-5} and 10^{-6} M Cd were approximately 114, 59, 24 and 4 times the control, respectively. However, the plants transported only a small amount of Cd to their bulbs and shoots, concentrations in these tissues were found to be low relatively.

Legumes are ideal for revegetation of metal-mined wastelands which are lack of nitrogen. A greenhouse study was conducted from Ye et al. (2001). They investigated the feasibility of

using *Sesbania rostrata* and *S. cannabina* for the reclamation of Pb/Zn mine tailings and to evaluate the effects of organic amendment using sewage sludge (0%, 25%, 50%, and 75%, v/v). The results showed that both species could continue to grow on the highly toxic tailings substrata for at least 80 days, although their growth suffered from adverse effects. Stem and root nodules of *S. rostrata* had better development (biomass, growth rates, and biomass of nodules) than that of *S. cannabina*. It was suggested that *S. rostrata* was a better choice as a pioneer species for re-vegetation of the mine tailings.

Magia *et al.* (2005) surveyed the concentrations of some toxic and essential metal ions in seven medicinal and edible plants from Mali. Dry ashing of the plant material and subsequent use of atomic absorption spectrophotometry were used as analysis instrument. Fe, Mn, and Zn were found in high concentrations in some of the plants, i.e., 1.4 and 1.5 mg g⁻¹ Fe in *Cuminum cyminum* and *Bombax costatum*, respectively, 243 µg g⁻¹ Mn in *Hibiscus sabdariffa*, and 62.8 and 67.1 µg g⁻¹ Zn in *Spilanthes oleracea* and *B. costatum*, respectively, whereas Co and Cd were not detected in any of the plant material studied. Cr, Ni, Pb, and Cu, were also found in minor amounts, in the ranges of 2.2-17.2 µg g⁻¹ for Cr, 1.6-8.1 µg g⁻¹ for Ni, 0.7-5.2 µg g⁻¹ for Pb, and 2.4-17.1 µg g⁻¹ for Cu. From a toxicological point of view, none of these plants would be harmful for the consumers by taking in the plant material in the traditional manner, which is preparing an infusion of the plant using amounts not adding up to those necessary to reach a harmful level of the metal ions detected. The plants *B. costatum* and *C. cyminum* could be of interest as sources for iron for humans in the case of too low of a level of hemoglobin.

In Brazil, Caldas (2004) analyzed samples of herbal medicine, ginkgo biloba (*Ginkgo biloba*), celastraceae (*Maytenus ilicifolia*), cascara buckthorn (*Rhamnus purshiana*), eggplant (*Solanum melongena*), horse chestnut (*Aesculus hippocastanum*), Brazilian ginseng (*Pffafia glomerata*), centella asiatic (*Hydrocotyle asiatica*), guarana (*Paullinia cupana*), artichoke (*Cynara scolymus*) and chlorella (*Chlorella pyrenoidosa*). Cd, Mg and Pb were not detected in fifteen samples (limit of quantifications of 0.20, 0.01 and 2.0 mg kg⁻¹, respectively). They were not found in the samples of in any sample of artichoke, eggplant and guarana. Cd was found in some samples of the other medicinal herbs at levels up to 0.74 µg g⁻¹ and Mg up to 0.087 µg g⁻¹. Three samples of horse chestnut contained 153, 156 and 1480 Pb µg g⁻¹, while the highest concentration was found in the other samples to be 22 Pb µg g⁻¹. The estimated lead intake through the consumption of horse chestnut reached 440% of Provisional Tolerable Weekly Intake (PTWI), and might be of concern to consumers if the medicine was taken on a long-term basis. Exposure to Cadmium and mercury through the herbal medicines does not appear to be of health concern.

Aiming the possibility of translocation of heavy metals into humans and animals, Dwivedi and Dey (2002) studied 28 on commonly used medicinal plants and scored their heavy metal content. The plant materials were collected from the same sources practiced by traditional healers and commercial drug manufacturers. The mean Pb concentration in medical herbs ranged between 2.624 ppm (standard deviation = 0.426) and 32.757 (standard deviation = 0.124 ppm), and the cadmium concentration ranged between 0.056 ppm (standard deviation = 0.002) and 0.419 ppm (standard deviation = 0.006). Interestingly, the heavy metal concentrations (i.e., Pb and Cd)

were higher in leaf than in stem bark or roots, and the lowest values were recorded in seeds.

Current researches revealed that pot marigold (*Calendula officinalis*) and hollyhock (*Althaea rosea*), mostly planted ornamentally, grew normally in soils containing high amount of Cd and Pb without suffering phytotoxicity and can be remedy for contaminated environment. Black nightshade (*Solanum nigrum* L.), another ornamental and medicinal plant, was determined as a Cd-hyperaccumulator. The Cd accumulation capacity coupled with its relatively high and tolerance ability could make it useful for phytoremediation of sites co-contaminated by Cd and As (Liu et al.; Sun et al., 2007).

4. CONCLUSION

Some medicinal plants such as mint, St. John's wort, lavender, marigold, hollyhock, caraway, garlic, garden sorrel, common hemp etc. can accumulate high amount of toxic heavy metal in their tissues. They can also take part in phytoremediation successfully than other plants grown under the same conditions.

Environmental pollution with metals and xenobiotics is a global problem, and therefore the development of phytoremediation technologies for plant-based clean-up of contaminated soils is therefore a significant interest (Krämer, 2005). Phytoremediation technologies are currently available for small subset of pollution problems. Unfortunately, further studies are still needed to find ways, which would be applied on large scale. On the other hand, they are clean, efficient, inexpensive and non-environmentally disruptive.

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