REMEDIATION OF HEAVY METAL CONTAMINATED SOILS BY USING *URTICA DIOICA*

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Abstract
Soil pollution with heavy metals not only degrades soil fertility, but also negatively affects the human health and well-being through the food chain. In order to protect the soil, as well as other parts of the environment, special attention should be paid to the remediation techniques of soil contaminated with heavy metals. The majority of physical and chemical remediation techniques, despite of their high efficiency, are expensive, environmentally destructive, harmful to soil fertility and therefore not well accepted by the public. Therefore, the use of environmentally friendly and cost-effective biological remediation techniques is a more acceptable approach for the remediation of contaminated soil. Phytoremediation is an eco-friendly approach that using native plants for remediation of heavy metal polluted soil in a cost-effective way. The aim of this paper is review of the most important results about of using plant stinging nettle (*Urtica dioica*) for removal of heavy metals from polluted soil.

Keywords: polluted soil, heavy metals, phytoremediation, *Urtica dioica*

Introduction
Heavy urbanization and industrialization, intensive mining and smelting activities, and the overuse of pesticides and other chemical additives in the agricultural sector have had a huge input into the degradation of vast areas by heavy metal contamination [1]. Heavy metals are the most studied among soil pollutants due to their persistence in the soil ecosystem [2]. Heavy metals are non-degradable by any biological or physical processes and remain in the soil for a long time, which poses a long-term threat to both the environment and human [3]. An excess of potentially toxic metals may be present due to natural geological sources or they may be introduced into ecosystems through anthropogenic processes [4]. They can enter into the food chain through crops and accumulate in the human body through biomagnification, thus posing a great threat to human health [5].
The possibility of remediation of the contaminated environment using different plant species attracts the attention of many scientists compared to the application of traditional expensive technologies for cleaning up contaminated sites. Methods, such as excavation, thermal treatment and chemical soil washing are typically expensive and destructive [6]. Phytoremediation, i.e. the application of plants for the restoration of a polluted environment, has been proposed as a promising green alternative to traditional physical and chemical methods [3]. Various plant species have mechanisms for the detoxification of xenobiotic compounds, with some being tolerant to high concentrations of toxic compounds and able to hyperaccumulate up to 1% of their weight [7]. Plant cultivation and harvesting are inexpensive processes compared with traditional engineering approaches involving intense soil manipulation [8].
The degree to which metals are available for plant uptake and further accumulation in the food web strongly depends on the degree of pollution and soil physico-chemical properties [9]. The

uptake of metals from soil depends on different factors such as their soluble content, soil pH, plant growth stages, types of species, etc. [10]. Modeling the translocation of metals from soil to root and root to the other parts of a plant, can be a very useful tool in heavy metal contamination and biological monitoring, in addition to the selection of tolerant or metal accumulator species [11]. The process of metal translocation in plant species is a very important factor that determines the distribution of metals in different plant tissues [12]. Several factors, including biochemical, anatomical, and physiological ones [13] determine the level of accumulation and distribution of heavy metals in the upper vegetative parts of plant.
To date, around 450 heavy metal hyperaccumulating species belonging to 45 families have been identified [14] and one such reported hyperaccumulating plant is stinging nettle (*Urtica dioica*).

Stinging nettle *(Urtica dioica)* and its potential for removing heavy metals from contaminated soil

The stinging nettle (*Urtica dioica*) belongs to the *Urticaceae* family and represents a perennial plant. The word "nettle" refers to the stinging effects of the tiny hairs on the stems and leaves, which when rubbed against the skin cause a burning sensation and temporary rash. It is widespread throughout Europe, America and Asia in different areas from temperate to tropical and it is easily adapted to many climatic conditions [15]. The main benefit of this plant species is its simplicity in terms of nutrition requirements, moreover, nettles are considered weeds due to their rapid growth and soil coverage. Stinging nettle is abundant species occuring in various types of forest, road verges and grassland sites. Stinging nettle is a plant that grows wild in the landfills and due to its ability to accumulative heavy metals in its organs, is a suitable plant species for their removal from soil [16].

In study of Bislimi et al. [11] was investigated the translocation and bioaccumulation of heavy metals such as Pb, Ni, Cd, Cu, and Fe in *Urtica dionica* and soil samples from two sites (uncontaminated and contaminated). In the contaminated site, the mean level of all the metals in soil and different parts (root, stalk, and leaf) of the plant were found to be significantly ($p<0.01$) higher than the uncontaminated site. The results revealed that *Urtica dionica* translocated high amounts of metals to its organs, especially to leaves, so that translocation factors were much higher than one (>1). On the basis of this study it can be concluded that the uptake of heavy metals from the soil to different parts of plant can be a very good biomonitoring tool for the heavy metal contamination or determination of species with high accumulation factor [11].
Shams et al. [17] examined the possibility of using the plants *Urtica dioica*, *Brassica napus* and *Zea mays* for the phytoremediation of sites contaminated with chromium and concluded that among the examined plant species, *Urtica dioica* was very effective due to its higher chromium uptake capacity (the aboveground concentrations of Cr in nettles was remarkable about 10 mg/kg). Their experiments were carried out without any chelating agents that could artificially enhance its uptake capacity. *Urtica dioica* with a mild presence of K in the chemicals produced very promising results to be considered as a unique plant for chromium remedial purposes [17].
In the study Grubor [18] specimens of *Urtica dioica* and *Sedum spectabile* collected from uncontaminated sites and transplanted in lead contaminated soil without additives (EDTA, HEDTA) to identify their natural potential for hypertolerance and hyperaccumulation of lead. This research showed that the concentrated toxic levels of lead in *Urtica dioica* and *Sedum spectabile* were about 100 or more times higher than those of non-accumulator plants, so these plants showed a natural hyper-accumulator and hyper-tolerant properties, because they have accumulated large amounts of lead without any additions - chelating compounds (EDTA,

HEDTA), to increase the uptake of lead from the soil. The results of the study by Dimitrijević et al. [19] also have shown that nettle has a tendency to accumulate lead.
According to Balabanova et al. [20] *Urtica dioica* showed potential to be used for phytoextraction for copper but not much specific potential for lead, as previously investigated by Grubor [18].
Research by Sharifi et al. [16] aimed to evaluate the absorption and accumulation of heavy metals from a simulated landfill soil using nettle. The researchers collected nettle seeds from the Tonekabon landfill, planted them in pots and after reaching the 6-leaf stage, the plants were exposed to three concentrations of four heavy metals (Pb, Cd, As and Ni) during the growing season. The results of this research showed that increases in the concentrations of the heavy metals in the soils led to their higher concentrations in all organs of the nettle plants (Pb > Ni > Cd > As), and larger quantities of the heavy metals were accumulated in the aerial parts of the plants. The results of Sharifi et al. [16] showed the ability of nettle to accumulate more heavy metals when they are present in higher concentrations in the soil.
Viktorova et al. [7] examined the plants of *Utrica dioica* which were cultivated in pots with two types of contaminated soil: first type was collected from the dumpsite of a long-term polychlorinated biphenyls (PCB) - contaminated soil in Lhenice (Czechia) and second type was obtained from mining ore at Pribram (Czechia) with excessive levels of As, Cd, Pb and Zn. The researchers in this study found a decrease in the concentration of heavy metals in soil samples for lead 4.9 ± 0.2%, for cadmium 5.3 ±0.4% and zinc 19.4 ± 0.8%, while arsenic was undetectable in nettles in this study. This investigation provided the first report that focused on remediation of PCBs with nettle. The researchers concluded that the nettle is only able to remediate less chlorinated biphenyls and determined a decrease of up to 33% for trichlorinated biphenyls (congeners 13–39), up to 12% of tetrachlorinated biphenyls (congeners 40–81) and other chlorinated biphenyls were hardly removed at all [7]. Even though their overall remediation is not very high, the remediation that they do perform is highly important.

Conclusions

Contamination of soil by various heavy metals is increasing as a result of different activities. These potentially harmful and persistent metals pose a great threat to the environment and human health. In order to protect the soil, as well as other parts of the environment, special attention should be paid to phytoremediation, as an eco-friendly approach that using native plants for remediation of heavy metal polluted soil in a cost-effective way. The stinging nettle (*Urtica dioica*) represents a perennial plant, which is widespread throughout different areas and easily adapted to many climatic conditions. The main benefit of this plant species is its simplicity in terms of nutrition requirements, moreover, nettles are considered weeds due to their rapid growth and soil coverage. *Urtica dioica* is one of the hyperaccumulating plants and its potential to remove heavy metals such as Cr, Pb, Cu, Ni, Cd and Zn from the polluted soil has been confirmed in several studies. Recent research has shown that *Urtica dioica* can be used not only for phytoremediation of heavy metals, but also for organic pollutants, which is highly important.

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