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Research Paper

An Investigation on the Removal of Heavy Metals from Contaminated Soils with Ornamental Plants

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Abstract: Pollution caused by heavy metals is one of the important issues that spreads rapidly in urban, rural, and industrial areas and has great environmental impacts. Although it is possible to remediate soils contaminated with heavy metals using chemical, physical or biological techniques, physical and chemical methods of remediating areas contaminated with heavy metals are costly, time-consuming, and environmentally damaging. Therefore, in recent years, scientists and engineers have tried to design and develop biological techniques that can clean and replace places contaminated with heavy metals without causing negative effects on soil fertility and biodiversity, and as a result, they have introduced "Phytoremediation Systems". Many ornamental plants can extract several toxic metals from the soil and store them in large amounts in their organs, and at the same time survive without showing signs of toxicity. This article aims to explain the potential use of ornamental plants for phytoremediation of polluted environments and their effects on the landscape. This study focuses on phytoremediation and ornamental plants used in landscape architecture according to the type of pollution. Through a comprehensive literature review, it has been revealed that these plants can be used and that they form an important basis in purifying environmental pollution in landscaping works. According to the results obtained, while making rearrangements in the relevant areas in the future, they will provide greenery to the environment with ornamental plants, as well as providing healthy, aesthetic, and visual living spaces that are open to people's use.

Keywords: *Heavy metals, ornamental plants, contaminated soil, phytoremediation*

Introduction

Heavy metals are compounds naturally found in the earth's crust. Recently, because of the development of the industry and mining activities, pollution caused by heavy metals has become an important issue attracting worldwide attention. The toxicity of heavy metals and their accumulation in food chains is one of the main environmental and health problems of modern societies. Soil, water, and air pollution creates environmental pollution in nature in the form of a triple circle and affects all ecosystems, including humans. Pollution that cannot be transformed and eliminated in nature is soil pollution. Agriculture cannot be done in polluted lands and these lands remain idle. Soil pollution is the ultimate source of water pollution and air pollution in nature. Today, heavy metal pollution in soil is one of the important environmental problems (Çağlarırmak & Hepçimen, 2010).

Heavy metals are among the environmental pollutants found everywhere in industrial societies (Lasat, 2002). In terms of their physical properties, the term heavy metals refer to metals and semimetals with a density of more than 5 gr cm^{-3}. Lead (Pb), Zinc (Zn), Copper (Cu), Cadmium (Cd), Nickel (Ni), Arsenic (As), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Cobalt (Co), Magnesium (Mg), mercury (Hg), chromium (Cr), silver (Ag) and selenium (Se) are among these metals. The toxicity of heavy metals and their accumulation in food chains is one of the main environmental and health problems of today's societies (Adriano, 2001; Baba et al., 2009; Çağlar Irmak & Hepçimen, 2010; Al-samman et al., 2022). Soil pollution caused by heavy metals differs from water or air pollution because heavy metals remain in the soil longer and are more durable and persist in the soil than in other parts of the biosphere (Lasat, 2002). In the research conducted in Hungary, the effect of soil pollution caused by heavy metals on microorganisms in the soil was investigated. While heavy metal pollution was detected at low levels in polluted soil, Cr and Cd rates were determined to be high according to the Hungarian Soil Pollution Regulation. Cr and Cd rates in polluted soils were found to be significantly high (Mathe Gasper et al.,

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2005). In the research conducted in China; Heavy metal contents of 268 vegetable samples grown in soil contaminated by different reasons such as mining, agriculture, industrial activities, and traffic density were determined. It has been determined that the Pb, Cd, Cr, Hg and as levels in celery, carrots, cabbage, tomatoes, asparagus, lettuce, and red peppers are higher than the level that does not pose a risk to health as stated by the Environmental Protection Agency (EPA), and the contamination rate varies according to vegetable types (Liu et al., 2013). Heavy metal levels in alcohols and wines made from fruits produced in certain areas in Italy, Poland and Bulgaria and using pesticides and fertilizers were higher than the level legally permitted by the European Union (Formicki *et al*., 2012).

Factors that cause heavy metals to spread into the environment are primarily industrial activities, pesticides and fertilizers used in agriculture, urban waste, motor vehicle exhaust fumes, mining operations and volcanic activities (Stresty & Madhava, 1999). Heavy metals accumulated in the soil not only affect soil fertility and ecosystem functions, but also have significant effects on human and animal health through the food chain. Heavy metals can contaminate the environment in various ways, such as meat and milk from animals fed on grass contaminated with metals, grains from the environment, fish caught from polluted waters, or from tools and equipment used during food production. They can pass into industrial wastes, drinking water, groundwater, air, and soil (Erkmen, 2010).

In this study, information was given about the important effects of heavy metals on human health and ornamental plants used in soil reclamation in landscape architecture were investigated according to the type of pollution. In this regard, concerns have been raised about the potential effects of heavy metals on vegetation and the phytoremediation potential of ornamental plants, soil pollution in urban areas and plant breeding technology.

Material and Method

The main material of the study consists of the data obtained because of literature searches to find the answer to the question of what ornamental plants can be used by landscape architects to provide visual living spaces in the reclamation of soils contaminated with heavy metals and healthy landscaping. The method of the study consists of analysis, synthesis and evaluation of the data obtained through extensive literature reviews on this subject. The results of research and investigations on the subject are presented in the following order.

Effects of Heavy Metals on Human Health

If the concentrations of heavy metals exceed a certain level in soil, water, and atmosphere, they can cause serious problems for all living things. Heavy metals cause different diseases, especially cancer, in humans, depending on factors such as the person's immune resistance, general health status, genetics, nutritional level and age, as well as the dose they are exposed to. Protecting natural resources and the environment against contamination is very important in preventing environmental pollution (Wu et al., 2018; Yasin et al., 2021). However, purifying contaminated areas is of great value in solving existing environmental pollution. Removal of heavy metals found in soil and water, which are harmful to human health, by using classical physicochemical techniques is a method that is costly and limited in use. Plants are considered important tools for soil and water remediation (Prasad, 2007; Poddar, 2023). For this reason, it is of great importance to remove heavy metals in soil and water by using the phytoremediation technique, which is easy and cheap to apply and allows the removal of heavy metals from the soil by natural methods, with the help of different hyper accumulator plants that can vary depending on the concentration and type of heavy metal in the soil.

Heavy metals are non-biodegradable, bio accumulative, and are ubiquitous in nature. They can enter the food chain and cause various diseases and disorders in plants, humans, and animals (Erkmen, 2010; Yasin *et al.*, 2021; Siddique *et al.*, 2013). According to a report published by USEPA (2016), there are approximately ten million people worldwide affected by metal-contaminated soils. Similarly, excessive amounts of heavy metals in the soil restrict the growth of vegetation due to phytotoxic effects and make the soil prone to erosion, causing pollutants to disperse to new areas (Deepika & Harikash, 2023). Table 1 lists the main effects of heavy metals on humans.

The types of heavy metals that accumulate in the soil and the effects they cause are also different: Lead: Grains, vegetables, fruits, seafood and meat, some types of beverages, water and spices may contain Pb, both in natural and contaminated form (Tayfur, 2009). It has been determined that foods contain Pb in an average amount of 0.065 mg kg^{-1} (Food Standard Agency, 2009). Lead exposure can cause acute proximal renal tubular damage, chronic nervous system disorders, anemia, colic, chronic renal failure, blindness, and damage to vitamin D metabolism (Ärup, 2003).

Table 1. Main effects of heavy metals on humans (Jorge et al., 2005; Wu et al.,2016; Siddique & Al-Samman, 2022; Deepika & Harikash, 2023).

Metal	Effects
Arsenic (As)	Cancer, chromosomal abnormalities, diabetes, cardiovascular disease, liver and kidney damage, pulmonary disease, anaemia, peripheral neuropathy and skin irritations
Cadmium (Cd)	May cause kidney damage, lung disease, hepatocellular injuries, cancers, as well as diabetic complications, hypertension and osteoporosis, gastroenteritis
Chromium (Cr)	Allergic dermatitis, kidney damage, respiratory and stomach cancer, neurological and cardiovascular disorders, premature death, ulcer, liver necrosis
Copper (Cu)	Gastrointestinal upset, liver, or kidney damage
Mercury (Hg)	inorganic Kidney damage, neuropsychiatric disorders, birth defects, insomnia, weight loss, gingivitis, delusions and hallucinations
Nickel (Ni)	Lung, nose, lung, throat and stomach cancer, dermatitis, lung fibrosis, cardiovascular and kidney disease due to inhalation of nickel
Lead (Pb)	Delays physical and mental development in children, Kidney damage and high blood pressure problems, miscarriages and birth defects in adults, DNA damage and neurological disorders, hypertension, encephalopathy in both children and adults.
Zinc (Zn)	Excessive zinc intake (150 mg/day-1-2 g/day) causes sideroblastic anaemia, hypochromic microcytic anaemia, leukopenia, neutropenia and gastrointestinal bleeding.

Potential Effects of Heavy Metals on Vegetation

Increasing heavy metal concentration in soil affects plant growth and fertility. Increased metal concentrations in plant tissue could bring various biochemical, physiological, and morphological toxic effects. In non-resistant plant species, heavy metals affect a wide range of plant cellular activities, including photosynthesis, respiration, mineral nutrition, cell membrane properties and structure, and gene expression (Majer et al., 2002). Cadmium is one of the most dangerous soil pollutants with adverse effects. Metal toxicity in plants interrupts water and nutrient uptake and transport, changes nitrogen metabolism, restricts plant growth by reducing photosynthetic activity, and causes stomatal closure due to malfunction of the photosynthetic mechanism of plants (Athar et al., 2018). Conversely, some plants have evolved the ability to grow in metallic soil, as observed in mining sites (Gardea-Torresdey *et al*., 2005), and the concept of developing tolerance to metal exposure is referred to as 'adaptation'.

Plants require some heavy metals in very low concentrations, but when the concentration of these metals is higher than the plant's need, it causes metabolic disorders and inhibits the growth of most plant species (Majer *et al*., 2002). A summary of the effects of heavy metals Arsenic, cadmium, chromium, copper, mercury, nickel, lead, and zinc on plants is available in Table 2.

Table 2. Main effects of heavy metals on plants (Jorge *et al*., 2005; Deepika & Harikash, 2023).

Metal	The effects
Arsenic (As)	Chlorosis, inhibition of growth process, oxidative stress
Cadmium (Cd)	Reduction of seed germination, lipid content and plant growth; causes browning of root tips and chlorosis and eventually plant death,
Chromium (Cr)	Reduction of enzyme activity and plant growth; Damage to the cell membrane and root of the plant, yellowing of the leaves
Copper (Cu)	Inhibition of photosynthesis, plant growth and reproduction processes, leaf yellowing
Mercury (Hg) inorganic	Reduction of photosynthetic activity, water absorption and antioxidant enzymes; Phenol and proline accumulation interferes with Mitochondrial activity, oxidative stress, binding to water channel proteins,
Nickel (Ni)	Reduction of seed germination, dry matter accumulation, protein, chlorophyll, and enzyme production; Increase in free amino acids
Lead (Pb)	Decreased chlorophyll production and plant growth; Production of reactive oxygen species, water imbalance, disruption of membrane permeability and mineral nutrition, toxic effects on the morphology, growth and photosynthetic processes of plants.
Zinc (Zn)	Chlorosis, Delayed growth, aging and inhibition of metabolic functions.

Phytoremediation Potential of Ornamental Plants

Phytoremediation removes heavy metals, organic pollutants, petroleum by-products, etc. from the soil. Plants with shorter life cycles that are economically important in groundwater are persuading researchers to engage in phytoremediation to remove hazardous substances from the environment. Although it has been used for many years, phytoremediation is still a relatively new technology (Kristanti & Hadibarata, 2023). The concept of phytoremediation was first proposed in 1983 and the process is still evolving. It is the best approach to deal with moderately metal-contaminated sites and can be applied along with other conventional remediation technologies for effective removal of pollutants (Deepika & Harikash, 2023). Plant breeding is a cost-effective and ecologically benign alternative to traditional breeding methods. Phytoremediation is a sustainable method of cleaning up polluted areas as it helps restore ecosystems and biodiversity. Third, environmental managers and policymakers should consider using phytoremediation to address widespread contamination (Poddar, 2023). Wu et al., (2018) stated that approximately 721 hyperaccumulator species were reported, including 59 from the Phyllanthocin and 83 from the Brassicaceae family. Despite numerous types of research, phytoremediation is not effectively used commercially due to the plants' long growing seasons, low biomass production, risk of entering the food chain, poor disease resistance, and shallow root systems (Wei et al. 2008; Liu et al., 2011). Ornamental plants are herbaceous plants that have the advantages of short growth period, high biomass, high adaptability, wide distribution, and low toxicity risk. In addition, these plants can provide economic benefits and improve the aesthetic appearance of the contaminated area (Deepika & Harikash, 2023).

Ornamental plants provide a different aspect to the phytoremediation of polluted terrestrial and aquatic environments. Ornamental plants are grown for aesthetic reasons and include a wide variety of plants of different sizes, colours and shapes that grow in different types of land and climate. Ornamental plants generally include different types of plants, from low to high, from herbs to shrubs, and from marine to terrestrial. Additionally, since ornamental plants are not eaten, the risks of hazardous substances, especially heavy metals, have less chance of entering the food chain. In addition to cleaning the environment, ornamental plants also have additional benefits such as increasing environmental aesthetics and providing additional income as well as additional employment opportunities (Işık, 2004; Kaushal *et al*., 2023).

According to Poddar (2023), it is a green technology that uses plants to clean, stabilize and eliminate environmental toxins. In Poddar's study, use of *Helianthus annuus* to remove radioactive contaminants from water in Chernobyl, Ukraine; *Salix* Spp. to stabilize and reduce heavy metals in soil in Silver Bow Creek, Montana. use: and discussed the use of *Alpine pennycress* to remove heavy metals from contaminated soil in Bunker Hill, Idaho, USA. Large-scale phytoremediation projects at Chernobyl, Silver Bow Creek, and Bunker Hill demonstrate the promise of this approach to dealing with pollution at the landscape scale. Phytoremediation involves several specific processes discussed below:

In phytostabilization, plants immobilize or stabilize pollutants in contaminated areas by accumulating them on roots or root hairs, causing adsorption on the root surface, or precipitation in the rhizosphere of a plant (Muthusaravanan et al. 2018), thereby reducing the bioavailability of pollutants in the environment (Lee, 2013). Various reports indicate that plants from the Fabaceae and Brassicaceae families are often involved in the phytostabilization process (Tordoff et al., 2000). *Festuca rubra, Agrostis tenuis, Zygophyllum fabago, Lupinus angustifolius, Horedeum vulgare, Brassica juncea, Secale cereale, Helianthus annuus* (Ghosh & Singh, 2005).

Phytoextraction is a process by which a plant's roots absorb pollutants from soil or water, then transfer and store these pollutants into aboveground tissues such as shoots and leaves. Plants used to perform phytoextraction must have the ability to produce high biomass to accumulate pollutants without visible symptoms. This method is only applicable to areas with low to moderate levels of metal contamination. Aquatic plant species that could remove heavy metals from water resources; It consists of *Eichhornia crassipes, Hydrocotyle umbellata* L, *Lemna minor* L. and *Pistia stratiotes* (Prasad & Freitas, 2003).

Phytovolatilization, also known as Phytoevaporation, is the process by which pollutants are taken up and assimilated into the air spaces of the plant and then released into the atmosphere in the same or modified/less toxic form due to the metabolic and transpiration of the plants (USEPA 1999). The process is beneficial as it causes significant dilution and photochemical degradation of pollutants in the atmosphere (Ghosh & Singh, 2005). Some aquatic plants, such as *Typha latifolia* L., also could volatilize selenium into the atmosphere (Pilon-Smits, 2005).

Rhizofiltration removes pollutants or pollutants from aqueous waste streams, nutrient recycling systems, etc. It refers to the use of plant roots to filter, adsorb, precipitate, and concentrate excess nutrients (Lee, 2013). In general, terrestrial plants such as *Brassica juncea* (Dushenkov et al. 1995) and *Helianthus annuus* (Dushenkov et al. 1997) are considered more suitable for rhizofilteration because they produce longer, more extensive, and fibrous root systems that contain greater surface area for metal accumulation.

Phytodegradation, also known as Phytotransformation, is the use of plants and related microorganisms to break down organic pollutants. Certain pollutant-metabolizing plant enzymes are released into the rhizosphere, which plays an important role in pollutant transformation. This process can also be used for the degradation of organic compounds such as ammunition, chlorinated solvents, herbicides, insecticides, and inorganic nutrients (Schnoor et al., 1995).

In recent years, potential hyperaccumulators have become a very important and popular area of research. 'Hyperaccumulators' are plant species that can grow in metal-contaminated soil without exhibiting any phytotoxic symptoms and without accumulating significant amounts of heavy metals in aboveground tissues. To date, approximately 721 hyperaccumulators have been reported from 52 families (Huang et al., 2020).

Ornamental plants are considered potential material for phytoremediation programs due to their shorter growth cycles. These plants have beautiful forms, colors and patterns and have the potential to be used frequently for landscaping in urban and suburban areas. The fact that ornamental plants can be used to prevent pollution in urban areas and at the same time to beautify the environment represents the advantage of ornamental plants over other plants for plant breeding (Poddar, 2023; Deepika & Harikash, 2023). Such plants also represent higher biomass, rapid growth, diversity of plant species, vitality, economic benefits, and ultimately quality visual effects that increase landscape aesthetics. In addition, since these plants are not used as foodstuffs, they reduce the risk of contaminants entering the food chain (Vural, 1993; Prasad & Freitas, 2003; Li et al., 2020).

Metal concentration in ornamental plants may not always be high enough to be classified as a hyperaccumulator, as higher biomass yield may compensate for lower metal accumulation. For example, *Amaranthus hypochondriacus* and *Celosia argentea* are frequently used for phytoremediation because of their higher biomass yields and ability to grow under adverse conditions (Huang et al. 2020). Similarly, despite not being a hyperaccumulator, *Godetia grandiflora* accumulated 1014, 1180, and 1021 mg Pb/kg dry root weight in 1000, 1500, and 2000 mg Pb/kg soil, respectively (Manzoor et al. 2018).

Some ornamental plants such as *Urtica, Thlaspi, polygonum sachalase, Chenopodium*, and *Alyssum* could accumulate zinc, lead, cadmium, nickel, and copper in their bodies. The use of these plants is accepted as an indirect method of purifying polluted soils (Mulligan et al., 2001). Use of ornamental plants such as *Tagetes patula, Chlorophytum comosum*, *Limoniastrum monopetalum* (L.), T*agetes erecta, Helianthus annuus, Gladiolus grandiflorus, Chrysanthemum indicum, Calendula officinalis,* etc. has been reported for phytoremediation of heavy metal contaminated soils without showing any significant adverse effects on plant health (Poddar, 2023; Deepika & Harikash, 2023). In their study, Manios et al., (2003) examined the heavy materials collected by *Typha latifolia* from water and, because of the analysis, provided information about the heavy metals (Cu, Zn, Ni) collected in the highest amounts by the roots, stems and leaves of *Typha latifolia.* It has been determined that heavy metals are successfully removed from the environment thanks to some plants. For example; *Myripphyllum spicatum* (Cu, Pb, Cd, Ni, Zn), *Brassica Juncea* (Cu, Pb, Cd, Sr, Cr, Ni, Zn) and *Helianthus annuus* (Mn, U, Co, Cu, Cs, Cr, Cd, Ni, Zn), *Lemna minor*, *Eichornia crassipes* and *Hydrocotyle umbellata* species were successfully grown in a short time against many pollution factors (Meers et al., 2005; Epa, 2014). In their studies, heavy metals (Cd, Cu, Pb, Cr, Ni, Zn) accumulation and accumulation capacities were investigated. Willow species selected for research; *Salix triandra* 'Noir de Villaines', *Salix dasyclados* 'Loden', *Salix purpurea* × Salix daphnoides 'Bleu', *Salix fragilis* 'Belgisch Rood' and *Salix schwerinii* 'Christina'. According to Brooks et al., (1998), various plant species are used to neutralize various factors that create environmental pollution. Accordingly, *Thlaspi caerulescens* plant species for cadmium and chromium removal, *Haumaniastrum robertii* plant for cobalt removal, *Haumaniastrum katangense* plant for copper removal, *Macadamia neurophylla* for manganese removal, *Thlaspi* *ratundifolium* subsp for lead removal, *Alyssum bertoloni* and *Berkheya coddii* plant species for nickel removal, *Astragalus pattersoni* for selenium removal. *Iberis in removing* thallium *Atriplex confertifolia* plant species can be used for intermedia and uranium removal.

It has been determined that *Althaea rosea* and *Calendula officinalis*, which are ornamental plants that can be used outdoors, are tolerant to cadmium and these plants can be used in phytoremediation (Liu et al., 2008a). *Impatiens balsamina* (henna flower), *Calendula officinalis* and *Althaea rosea* alone were found to be tolerant to Cd and Pb pollution and could accumulate these metals effectively (Liu et al., 2008b). *Syngonia* sp. and *Tagetes patula* plants have been found to be usable in removing Arsenic pollution in the soil (Imamul, 2005). *Helinathus annuus* L. has been particularly successful in removing radioactive metals found in Chernobyl. After the Chernobyl disaster, sunflower fields were planted to collect these radioactive metals from the ground, and when the sunflowers were fully grown, they were harvested via pyrolysis and disposed of safely (Prasad, 2007). The list of some ornamental plants that can be used against heavy metals in green breeding is given in Table 3.

Table 3. Some ornamental plants that can be used against heavy metals (Brooks *et al*., 1998; Manios *et al.*, 2003; Ghosh & Singh, 2005; Meers et al., 2005; Liu *et al.*, 2008a; Epa, 2014).

Ornamental Plants	**Heavy Metals That Can Remove**
Althaea rosea	Cadmium, Lead
Calendula officinalis	Cadmium, Lead
Impatiens balsamina	Cadmium, Lead
Syngonia sp.	Arsenic
Tagetes patula	Arsenic
Pistia stratiotes	Silver, Cadmium, Copper, Chrome, Mercury, Lead, Nickel, zinc
Helianthus indicus	Mercury
Sesbania drummondii	Mercury
Lemna gibba	Arsenic
Alyssum SPP.	Nickel
Solanum nigrum	Cadmium
Thlaspi caerulescens	Cadmium, Chrome
Thlaspi ratundifolium	Lead, Nickel
Haumaniastrum robertii	Cobalt
Haumaniastrum katangense	Copper
Macadamia neurophylla	Manganese
Alyssum bertoloni	Nickel
Berkheya coddii	Nickel
Astragalus pattersoni	Selenium
Iberis intermedia	Talyum
Atriplex confertifolia	Uranium
Myripphyllum spicatum	Zinc, Copper, Lead, Cadmium, Nickel
Brassica Juncea	Zinc, Copper, Lead, Cadmium, Nickel, Strontium
Helianthus annuus	Zinc, Copper, Lead, Cadmium, Nickel, Manganese, Uranium

In order to prefer a plant to be used in a breeding method; It is necessary to have the ability to accumulate the heavy metal that is desired to be removed from the soil, and to have a high tolerance level to the concentration of heavy metal in the soil. Especially with the increase in pollution in urban areas, the use of ornamental plants in eliminating soil pollution should be taken into consideration by choosing the right species from ornamental plants, which have an important role in improving the beauty of the environment and at the same time.

Soil Pollution and Plant Breeding in Urban Areas

According to the United Nations, approximately 70 percent of the world's population will live in cities by 2050. Cities will face new challenges in sustainable development and seek different solutions. In urban areas, heavy metals such as Fe, Cu, Zn, Cd, Pb, Cr and Ni are generally found in the top layer of soil on the edges of streets and in the roots and leaves of plants growing in such areas (Athanasopoulou & Kollaros, 2016). This is mostly due to road traffic (Hercer *et al*. 2016; Rolka *et al*., 2020), combustion of fuels, consumption of motor vehicle oils, wear of tires and asphalt (Hołtra & Zamorska-Wojdyła,

2016) and maintenance work on the roads (Athanasopoulou & Kollaros, 2016). Due to the increasing flow of motor vehicles, both public transport and private vehicles, pollution with heavy metals caused by road traffic is one of the most serious dangers for the environment (Acar & Özkul, 2020). Higher metal content may have a negative impact on roadside vegetation (Khalilova & Mammadov, 2016), while hypersalinity of soils along roads may additionally worsen (Czerniawska-Kusza et al., 2004). In addition, such elements can pollute surface and groundwater (Athanasopoulou & Kollaros, 2016; Halilova & Memmedov, 2016) and accumulate in the environment and threaten human health (Önder et al., 2007; Halilova & Memmedov, 2016; Yap et al., 2022). The accumulation of heavy metals in roadside areas depends on various factors such as intensity of traffic flow, duration of exposure, age of vehicles (Athanasopoulou & Kollaros, 2016), distance from the road, depth of the soil profile, speed, and direction of the wind (Athanasopoulou and Kollaros, 2016; Rolka et al., 2020) and land aid (Rolka et al., 2020). Heavy metal emissions are compounded by the presence of industrial facilities that are potential emitters of such pollutants, often in the form of dust or smoke (Athanasopoulou & Kollaros, 2016).

In their study in Pakistan, Umer and Hüseyin (2023) revealed that the highest lead levels in the existing fuel and exhaust bodies of automobiles are present in the summer season, associated with increased wear and tear of automobile parts due to the high temperature of summer. Eight ornamental plant species commonly grown in various urban areas of Pakistan were tested for their lead hyperaccumulation potential and revealed *Bismarckia nobilis* and *Conocarpus erectus* plants as effective lead hyperaccumulator plant species.

Considering the harmful effects of heavy metals, precautions must be taken to minimize their effects on the environment and human health. In urban areas, especially along transportation routes, it is very important for landscaping to choose plants that can play a phytomediator role as well as fulfilling an aesthetic function (Widłak *et al*., 2017; Capuana, 2020; Rolka et al., 2020; Khan *et al*., 2021; Yasin *et al*., 2021). The success of phytoremediation depends on the volume of biomass produced, plant species, and bioavailability of metals (Sheoran et al., 2016). Moreover, successful implementation of the phytoremediation strategy depends on careful selection of genotypes, adjusting them to the contaminants therein. Great care should be taken in the selection of ornamental plants in an urban landscape (Capuana, 2020). Selection of multifunctional species is important in purifying the environment and improving the visual landscape value (Akpınar Külekçi, 2019; Capuana, 2020; Sezen and Akpınar Külekçi, 2020). In this direction, it is recommended to use local plants and consciously integrate them into the urban landscape.

However, the phytoremediation potential of plants is not considered, while their selection is often based on habitat conditions and aesthetic value. Thanks to their well-developed root systems, grasses are better than herbaceous plants at improving soil stability and forming compact vegetation, which means that they can be recommended for soil improvement purposes (Kompała-Bąba *et al*., 2021). The literature provides rich information about different plant species used for phytoremediation (Boros-Lajszner et al., 2021; Yasin et al., 2021). Considering that urban soils are exposed to a constant emission of pollutants, including trace elements, along transport routes, the choice of plants should be determined by their phytoremediation abilities. In this context, Rolka *et al*., (2022) determined in their study the phytomediator role of *Calamagrostis acutiflora* in heavy metal-polluted urban soils in Polnya and its adaptation to urban soils, revealing that this grass species could be an interesting choice in the landscaping of urban areas due to its high aesthetic value. Factors affecting phytoremediation of heavy metals; It consists of a few relevant factors such as soil properties, heavy metal type, and plant species (Deepika & Harikash, 2023).

Concerns About Plant Breeding Technology

One of the major concerns with phytoremediation technology is the low speed of this process compared to physical and chemical methods for remediating contaminated soils. Due to their slow growth, depending on climatic limitations and species diversity, it is possible that cleaning of a polluted area by plants may require many growing seasons. Plants with shallow roots can only cleanse the soil or surface water sources but cannot clean and improve the groundwater table and deep soil horizons (Sykes et al., 1999). There is also a risk of contamination of food chains by plants that absorb toxic substances because animals living in contaminated areas may feed on these plants (Moffat, 1995). Due to the strong adhesion of hydrophobic pollutants to soil particles, the phytoextraction technique is less effective for them (Bizily *et al*., 1999). On the other hand, evaporation of polluting compounds can turn a water or soil pollution problem into an air pollution problem. But the biggest concern is with the reclamation facility: what will happen to the metal-rich contaminated plants once they are harvested? It is possible that biodegradation or use of contaminated plants may fully or partially return contamination to the soil (Gratao *et al*., 2005). The answer to this question is still unclear.

Conclusions

The current situation of environmental pollution caused by heavy metals will affect all components of the ecosystem. Various techniques are used to treat contaminated soil. To restore the balance of the environment, the phytoremediation technique has many benefits, such as low cost compared to physical and chemical soil modification methods, no impact on soil biodiversity, and reduction of soil erosion. Therefore, it is one of the most suitable methods to deal with the problem of accumulation of heavy metals in the environment.

Some ornamental plants have a high potential for phytoremediation of many pollutants and remediation of polluted environments because they have many and diverse species, tolerate very high pollutant concentrations, and can grow in many soils and polluted environments. These plants have the feature of cleaning polluted environments, having economic and ecological values, and improving the quality of landscapes. They can also serve as a warning indicator for atmospheric pollutants and the growth environment. These excellent plants do not enter the human food chain and therefore do not pose any health problems to humans. Research shows that copper, cadmium, nickel, lead, zinc, mercury, arsenic, and chromium are among the heavy polluting elements and some ornamental plants can accumulate these metals in high amounts. In developed countries, a natural treatment system was planned by taking these negativities into consideration and as a result, "Phytoremediation Systems" were introduced. The biomass of ornamental plants produced after such activities can be used and sold as raw materials in the production of potted plants, cut flowers, essential oils, perfumes, air fresheners, and silk production.

In this study, information was given about the negative effects of heavy metals on human health, and ornamental plants used in soil reclamation in landscape architecture were investigated according to the type of pollution. The potential effects of heavy metals on vegetation and the phytoremediation potential of ornamental plants, concerns about soil pollution in urban areas and plant reclamation technology. has been revealed. As a result of the study, it is recommended that the mentioned ornamental plants be used in landscaping works of both urban and rural areas in order to eliminate heavy metal pollution, taking into account the climatic conditions and usage areas. Ultimately, these recommendations also highlight the importance of expanding the reach of phytoremediation through research, marketing, and funding so that it can fully realize its potential to make the world a cleaner, greener place. To design and select a scientific, accurate and comprehensive strategy, considering the type of metal ions presents in the soil or water, the geographical location and climatic conditions of the target area and the potential, the effectiveness of the mentioned method depends on the characteristics of the plant in removing pollutants from the environment.

Compliance with Ethical Standards Ethical responsibilities of Authors: *The author has read, understood, and complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors".*

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