

Ecological Aspects of Soil Pollution and Ornamental Planting

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Abstract

The research conducted has determined that soil pollution has a significant negative impact on the development of ornamental trees and shrubs. Comparative analyses have shown that in areas with high anthropogenic impact, the concentration of heavy metals (Pb, Cd, Zn, Cu, and Ni) in the soil increases, while the amount of humus and essential nutrients decreases. These changes cause serious violations in the morphological and physiological indicators of plants. It has been established that in polluted soils, the growth of ornamental plants weakens, the development of the root system slows down, the leaf surface area decreases, signs of chlorosis and necrosis are observed, and photosynthetic activity and overall decorative quality decrease. In contrast, in relatively clean areas, plants demonstrate high vegetative development, normal leaf structure, a strong root system, and stable physiological activity. The results of the research show that the ecological state of the soil is one of the main factors determining the sustainability of urban green systems. The introduction of ornamental plant species that can accumulate heavy metals is considered promising in terms of phytoremediation and can contribute to the improvement of the ecological state of polluted urban areas. The results once again confirm the need to reduce soil pollution, conduct regular ecological monitoring, recultivate contaminated soils, and use pollution-resistant ornamental plant species in urban landscapes. These approaches can serve to increase the ecological stability of urban ecosystems, protect green spaces, and improve environmental quality.

Keywords: urban ecosystems, soil degradation, green spaces, anthropogenic impact, decorative plants, phytoremediation

1. Introduction

In modern times, urbanization, industrialization, and the expansion of anthropogenic activities have turned soil pollution into a serious environmental problem. In urban and industrial zones, the soil cover is polluted with heavy metals, petroleum products, pesticides, and other chemicals. This situation negatively affects the growth, physiological state, and aesthetic appearance of ornamental trees and shrubs. Ornamental plants not only create beauty in the urban environment, but also participate in air purification, microclimate regulation, and preservation of ecological balance. Therefore, the study of the development characteristics of these plants in polluted soils is relevant. In existing studies, the accumulation of pollutants in the soil, their transfer to plant organs, and their effect on photosynthesis and growth processes occupy a central place. However, in the conditions of Azerbaijan, especially in Baku and urban areas exposed to industrial

influence, a comprehensive assessment of the development characteristics of ornamental trees and shrubs in polluted soils still requires separate research.

The main objective of the work is to study the effect of soil pollution on the development of ornamental trees and shrubs, to evaluate their morphological, physiological, and decorative indicators in polluted soil conditions, and to develop scientifically based recommendations for the selection of sustainable plant species. To achieve this goal, the main sources of soil pollution are analyzed, the development indicators of plants in polluted and relatively clean areas are compared, morphological and physiological changes are investigated, the selection of sustainable decorative species and the application of phytoremediation measures are justified.

Soil is an important component of the biosphere; it is an ecosystem where the living and non-living world coexist. Soil is a natural environment where many living organisms coexist. It plays an important role in providing living organisms with water, air, and nutrients. At the same time, it protects against sudden and sharp changes in the environment (Məmmədova, 2024, p. 12). According to Vernadsky, the soil layer represents a unique zone of interaction between the biocosmic substance of nature and living organisms and inert (non-living) matter. He considered the soil to be the "screen" and central link of the biosphere; It is here that the most important geochemical processes that affect fertility and the development of life occur.

Soil is not only one of the environmental factors, but also the main, most stable component of terrestrial ecosystems at all organizational levels, up to the biosphere. Soil is a component of the biosphere, a natural-historical body, the result of long-term interactions between rocks, climate, relief, and biota, and has the property of productivity (Məmmədov, 2007, p.9). Productivity is the main property that distinguishes soil from all other natural formations. Soil is a complex, multifunctional, open, four-phase structural system located in the surface layer of weathered rocks; it is a complex function of rocks, organisms, climate, relief, and time and has the property of productivity.

Rapid industrialization, urbanization, and intensive agricultural activities have led to rapid changes in soil ecosystems. The most serious consequence of anthropogenic impacts is soil pollution (Wang & Mulligan, 2019, p. 17). Soil pollution not only leads to a decrease in fertility but also to a general disruption of the ecosystem and causes harmful substances to directly threaten living organisms and human health through the food chain. As a result of the activities of industrial enterprises, a large amount of chemicals and waste enter the soil, which leads to changes in the soil ecosystem.

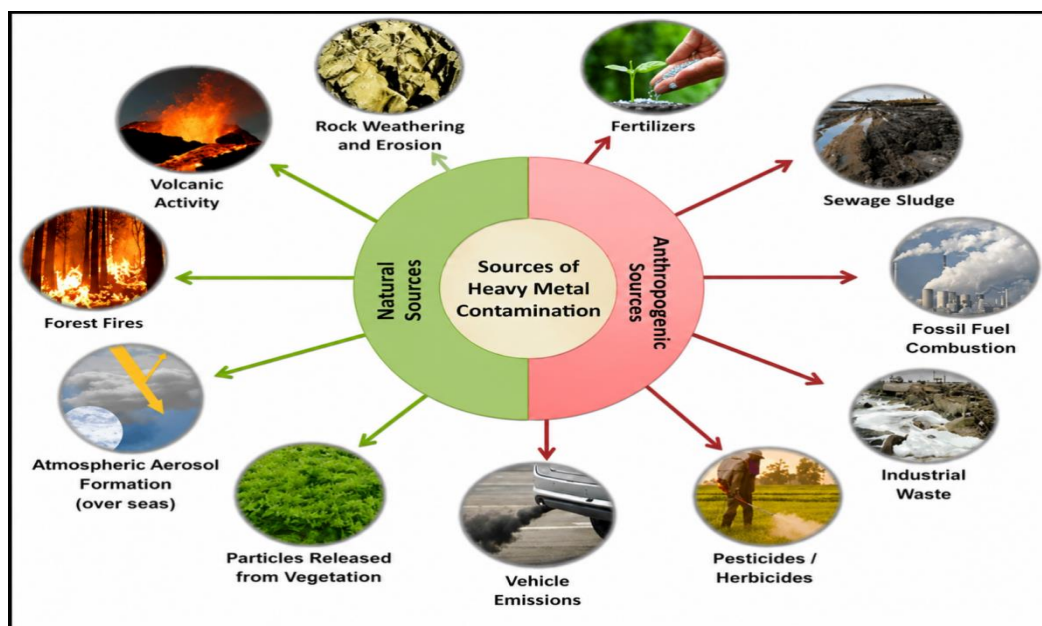


Figure 1. Natural and anthropogenic sources of soil pollution.

Figure 1 shows the main sources of soil pollution with heavy metals. Here, pollution sources are divided into two groups: natural and anthropogenic. Volcanic activity, rock erosion, atmospheric aerosols, particles released from vegetation, and forest fires are considered natural sources. Fertilizers, pesticides and herbicides, industrial waste, vehicle emissions, sewage sludge, and fossil fuel combustion are anthropogenic sources. As a result of these processes, heavy metals accumulate in the soil, weaken its ecological state, and negatively affect plant development. This process also leads to a decrease in organic matter in the soil and harmful substances entering the soil layers and groundwater. As they enter the soil layers, these substances are absorbed by plants, which both weakens plant development and enters the food chain, posing a threat to living organisms. Pollutants are absorbed from the soil layers by plants through the root system and accumulate in their seeds. The accumulation of harmful substances in plant seeds affects the normal development process of plants, weakens their growth, and disrupts their physiological processes. It is difficult to estimate the area of land that is contaminated each year; for this reason, there is no accurate global data, but the problem is widespread.

2. Migration of Heavy Metals in Soil and Their Toxicity to Plants

The term "heavy metals" was first used in 1817 by the German chemist Leopold Gmelin; he classified the chemical elements known at that time into three groups: non-metals, light metals, and heavy metals. Heavy metals enter the soil through wastewater discharged from industrial enterprises, causing pollution and degradation. Heavy metals include lead (Pb), cadmium (Cd), mercury (Hg), copper (Cu), zinc (Zn), nickel (Ni), and chromium (Cr) (Kabir, 2015, p. 27). These elements are present in nature in certain quantities, but an increase in the concentration of these elements poses a serious threat to the ecosystem and human health. Heavy metals enter the soil through various sources. Industrial enterprises are also one of the main sources. The chemical industry, metallurgical plants, oil refineries, and the energy sector emit heavy metal-containing waste into the atmosphere. The migration of heavy metals in soil depends on their chemical properties and soil characteristics – pH level, mechanical composition, organic matter content, and cation exchange capacity. In an acidic environment (low pH), the solubility of heavy metals increases, and they become more mobile, migrate to lower layers of the soil profile, and are more easily absorbed by plants (Xəlilov, 2009, p. 22). On the contrary, in an alkaline environment, most of these metals precipitate and become inactive, and their biological availability decreases.

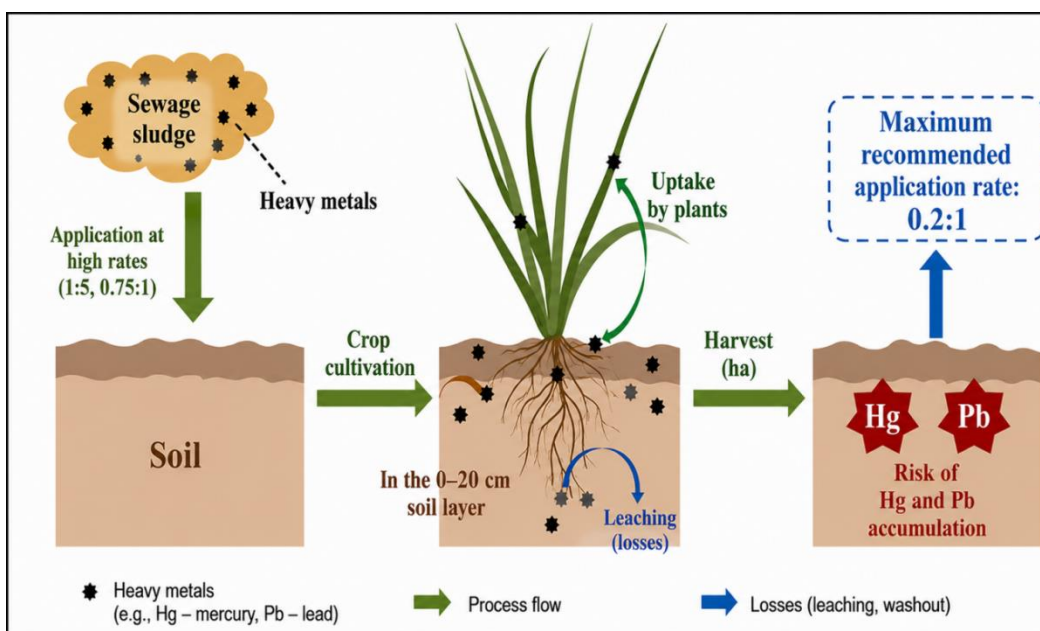


Figure 2. Movement of heavy metals in soil and toxic risk to plants.

Figure 2 shows that heavy metals entering the soil through sewage sludge accumulate in the root zone and are absorbed by the plant. Metal ions accumulate mainly in the 0-20 cm layer of the soil, from where they pass to the roots and accumulate in the tissues of the plant. Some of them leak into the lower layers with water, causing losses and additional pollution. When toxic metals such as Hg and Pb accumulate in the plant, growth, nutrition, and physiological processes are weakened. For this reason, they are widely used in various industrial processes; as a result, despite cleaning measures, the concentration of heavy metal compounds remains quite high in industrial wastewater. Of particular interest are metals that are used in the most extensive and significant quantities in industrial processes and pose a serious threat in terms of their biological activity and toxic properties because of their accumulation in the environment (Alloway & Ayres, 1997, p. 15). Many heavy metals such as iron, copper, zinc, and molybdenum participate in biological processes and are essential trace elements for the activity of plants, animals, and humans in certain quantities.

3. The Impact of Pollution on the Morphological Characteristics of Plants

Pollution of the soil ecosystem by technogenic and anthropogenic factors causes serious changes in both the internal biochemical processes and the external morphological structure of plants. Since plants are immobile organisms, they are directly exposed to the effects of toxic substances in the environment, and therefore their morphological characteristics are considered a visual indicator of the ecological state of the soil (Məmmədov et al., p. 26). The impact of pollutants in the soil environment on plant morphology can be analyzed in several main directions:

a) *Root system deformation*: The organ that first encounters toxic substances in the soil (especially heavy metals and oil residues). As the degree of pollution increases, root growth slows down, the main root shortens, and the branching of lateral roots is minimized. Necrosis (tissue death) occurring at the root tips sharply reduces the plant's ability to absorb water and minerals, which results in the weakening of the plant.

b) *Biometric indicators of aboveground organs*: The growth (height) of plants grown in polluted soil is significantly lower than their counterparts in clean areas. As a result of inhibition (slowing down) of cell division, the phenomenon of "dwarfism" is observed in plants. The diameter of the stem is reduced, the distance between the joints is shortened, and the total green mass (bioproductivity) of the plant is reduced.

c) *Pathologies occurring in the leaf apparatus*: Since the leaves are the center of the photosynthesis process, they are very sensitive to pollution. The following morphological changes are observed in the leaves due to the influence of toxic substances in the soil:

- Chlorosis: Yellowing of the leaf edge because of the breakdown of chlorophyll;
- Necrosis: The formation of brown, black spots on the edges of the leaves or between the veins;
- Epinasty: Folding of the leaves downwards and reducing their area;
- Defoliation: Premature shedding of the leaves as a defensive reaction of the plant.

d) *Impact on reproductive organs*: Soil pollution changes the duration and quality of plant phenological phases (flowering, fruiting). In a polluted environment, plants bloom less often, the pollination process is weakened, and the size of fruits and seeds is reduced. This not only leads to a decrease in current productivity, but also to a limitation of the future recovery of the plant population. Thus, these deviations in the morphological indicators of plants are an important biological test method that allows you to assess the degree of soil pollution. Soil pollution affects the morphological indicators of plants directly and indirectly, seriously disrupting their normal development process.

Pollutants, especially heavy metals, petroleum products, and chemical compounds, accumulate in the soil and enter the body through the root system of plants and cause various morphological changes in growth processes. One of the most observed effects is the weakening of plant height growth. Since the root system is damaged in polluted soil conditions, the absorption of water and nutrients decreases, resulting in a delay

in the development of shoots and stems. This leads to a reduction in the overall size of the plant and poor structural formation. There are also serious changes in the morphology of the leaves. Under polluted conditions, the size of the leaves decreases, their surface area decreases, and their color turns yellow or darkens.

In some cases, necrosis (formation of dead areas) and chlorosis (yellowing due to a decrease in chlorophyll) develop in leaf tissues (Məmmədova, 2024, p. 549). These changes weaken the plant's ability to photosynthesize. Deformation, thinning, and poor lignification (woodiness) are observed in the trunk and branches. This reduces the mechanical resistance of the plant and increases its sensitivity to external influences. In the root system, the development of the main and lateral roots weakens, the number of root hairs decreases, and the total root biomass index decreases. Changes in the flowering process are also observed in ornamental plants because of pollution. The number of flowers decreases, their size decreases, and the decorative quality weakens. In some cases, the flowering period is shortened, and the reproductive ability decreases. In general, soil pollution negatively affects the morphological development of both vegetative (root, trunk, leaves) and generative (flower, seed) organs of plants. As a result of this process, the aesthetic appearance of plants deteriorates, their ecological functions weaken, and their use in urban greening is limited.

Table 1. The effect of soil pollution on the morphological indicators of plants.

Morphological indicator	Changes observed under pollution conditions	Result
Increase in height	Weakening of growth, slowing down of development	Reduction of the overall size of the plant
Stem	Thinning, poor lignification, deformation	Decrease in mechanical strength
Root system	Weakening of root development, reduction of lateral roots	Weakening of water and nutrient absorption
Leaf size	Reduction of leaf surface	Reduction of photosynthesis area
Leaf color	Yellowing (chlorosis), darkening	Decrease in chlorophyll content
Leaf tissue	Necrosis, formation of drying areas	Disruption of the functional activity of the leaf
Flowering	Decrease in the number of flowers, premature wilting	Weakening of reproductive ability
General decorativeness	Fading of color, distortion of shape	Decrease in aesthetic quality

Table 1 shows the effect of soil pollution on the morphological indicators of plants. Changes in the morphological indicators of plants under soil pollution conditions are directly related to the disruption of their physiological and biochemical processes. The data presented in Table 1 show that the polluted environment has a complex negative effect on both the vegetative and generative development of plants. First, the observed weakening in height growth (height) indicates a decrease in the overall growth rate of the plant. This is mainly due to the slowing down of cell division and elongation because of the absorption of heavy metals and other toxic substances in the soil by the roots. As a result, the plant takes on a smaller and less developed form.

4. Specific Ornamental Shrub Species That Accumulate Heavy Metals

Ornamental shrub species that accumulate heavy metals play an important role in phytoremediation and ensuring urban ecological stability. In addition to having an aesthetic function, these plants are distinguished by their ability to absorb and partially neutralize toxic elements (Pb, Cd, Zn, Cu, Ni, etc.) accumulated in the soil. Such ornamental shrub species primarily include willow shrub forms (*Salix* spp.). Willow species can effectively remove heavy metals from the soil due to their rapid growth, extensive root system, and high biomass formation capacity.

Their phyto-extraction potential is highly appreciated, especially in humid and polluted areas. Another important ornamental shrub species is tamarix (*Tamarix* spp.). This plant shows high resistance to salty and polluted soils and can accumulate some heavy metals in its tissues, in addition to sodium and chloride ions. *Tamarix* is also used in the fight against erosion (Singh, 2019, p. 78). Common cranberries (*Berberis* spp.) also accumulate certain heavy metals. Since these plants are used for decorative purposes, especially in urban environments, their ecological function provides an additional advantage. Golden lilac (*Forsythia* spp.) and elm shrub forms (*Cornus alba*) are also distinguished by their moderate metal accumulation capacity. These species mainly participate in the phytostabilization process, limiting the spread of pollutants. In addition, ornamental shrubs such as hibiscus (*Hibiscus syriacus*) and ligustrum (*Ligustrum* spp.) are widespread in urban landscapes and, being relatively resistant to heavy metals, can also be used as bioindicators.

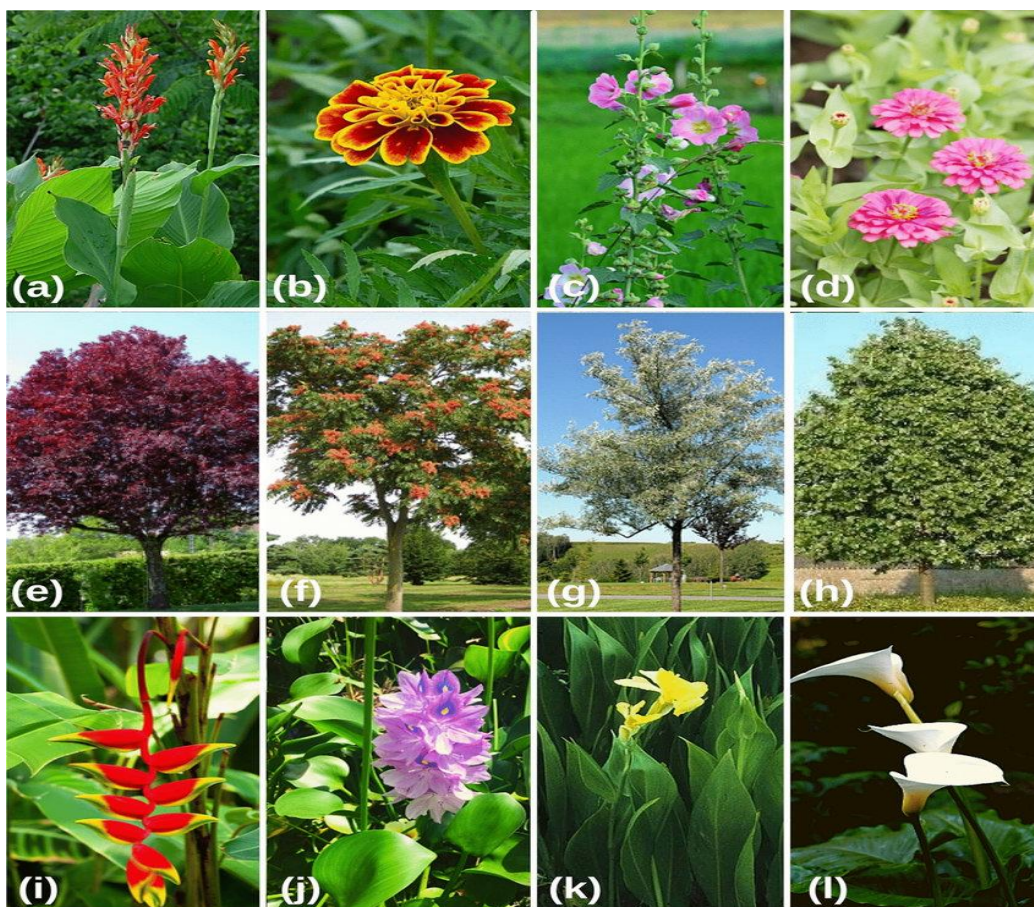


Figure 3. Ornamental plant species that accumulate heavy metals. **A.** *Canna* (*Canna* sp.); **B.** *Marigolds* (*Tagetes* sp.); **C.** *Lavatera* (*Lavatera* sp.); **D.** *Zinnia* (*Zinnia* sp.); **E.** *Plum blossom, decorative form* (*Prunus cerasifera* 'Atropurpurea'); **F.** *Ailanthus altissima*. **G.** *Poplar white* (*Populus alba*); **H.** *Linden* (*Tilia* sp.); **I.** *Heliconia rostrata*; **J.** *Eustoma grandiflorum*, formerly *Lisianthus russellianus*; **K.** *Lily of the valley* (*Hemerocallis* sp.); **L.** *Calla* (*Zantedeschia aethiopica*)

Figure 3 shows ornamental plant species that can accumulate heavy metals. These plants help restore soil by accumulating heavy metal ions in their root, stem, and leaf tissues in contaminated soils. The advantage of ornamental species is that since they are not used for food, the risk of pollutants entering the food chain is lower. *Cornus alba* (elm shrub forms) not only creates aesthetic value with its red decorative stem but also participates in the immobilization of elements such as Ni and Pb in heavy metal-laden soils. *Hibiscus syriacus* (shamama rose) creates conditions for both visual landscape enrichment in urban environments and the formation of a bioindicator role by demonstrating a certain degree of tolerance to metals such as Cd and Zn. *Ligustrum* spp. (privet) and *Viburnum opulus* (blackthorn) act as effective phytosequestrators in the accumulation of heavy metals with their dense leaf cover and high biomass formation capacity, and perform an ecological buffer function, especially in roadside and industrial impact zones.

In the research conducted to study the impact of soil pollution on the development of ornamental trees and shrubs, areas exposed to various degrees of anthropogenic impact in urban and suburban ecosystems were selected. Relatively less polluted green areas were taken as the object of the study to compare them with zones of Baku city with high industrial and transport load. This approach allowed us to comparatively assess the impact of changes in soil ecosystems on the morphological and physiological indicators of ornamental plants.

The research areas were defined in three main categories:

- Highly polluted zone - mainly areas along highways, close to industrial enterprises;
- Moderately polluted zone - inner-city parks and green areas;
- Relatively clean zone (control area) - areas far from the city, with weak anthropogenic impact.

Soil samples were taken from a depth of 0–20 cm in selected areas, and an average sample was formed for each area. During laboratory analyses, the main physicochemical indicators of the soil were determined: pH, humus content, total nitrogen, phosphorus and potassium content, as well as the concentration of heavy metals (Pb, Cd, Zn, Cu, Ni). The analysis conducted showed that as the level of pollution increased, significant changes occurred in the chemical composition of the soil (Məmmədova, 2024, p. 104). In highly polluted areas, the pH of the soil tended to become more alkaline, which weakened the ability of plants to absorb nutrients. While the pH in the control areas was relatively neutral (6.5–7.2), in areas exposed to industrial and transport impacts, this indicator varied within the range of 7.5–8.1. A decrease in the amount of the humus layer was also observed. Especially in highly polluted areas, the increase in the rate of decomposition of organic matter and the deterioration of the soil structure led to a decrease in the humus reserve. This weakens the water-holding capacity and aeration properties of the soil. The following table (Table 2) presents the summarized results of the soil analyses.

Table 2. Main mechanisms of the phytoremediation method.

Indicators	Highly contaminated zone	Moderately contaminated zone	Control zone
Ph	7.8	7.2	6.8
Humus (%)	2.1	3.4	5.2
Total Nitrogen (%)	0.09	0.14	0.21
Phosphorus (mg/kg)	42	58	76
Potassium (mg/kg)	110	145	190
Pb (mg/kg)	78	42	18
Cd (mg/kg)	1.9	1.1	0.4
Zn (mg/kg)	165	98	60
Cu (mg/kg)	74	46	25
Ni (mg/kg)	58	33	15

Table 2 shows the main mechanisms of the phytoremediation method. The results obtained show that there is a direct relationship between the level of soil pollution and the concentration of heavy metals. In particular, the high accumulation of elements such as lead (Pb), zinc (Zn), and copper (Cu) proves the intensive impact of industrial and automobile emissions on the soil. The accumulation of these elements in the soil disrupts the ion balance in the root system of plants and limits the absorption of nutrients. At the same time, the reduction of humus and basic nutrients weakens the biological activity of the soil.

This situation negatively affects the vegetative development of ornamental trees and shrubs, slows down their growth, and causes changes in the leaf structure. The indicators obtained in the control zone indicate that the soil has relatively stable and favorable conditions for plant development. Here, the low content of heavy metals and the balanced distribution of nutrients ensure the normal development of ornamental plants. Thus, soil analyses prove that anthropogenic pollution is one of the main factors that severely alters the chemical and biological properties of the soil, limiting the development potential of ornamental plants (Alloway & Ayres 1997, p.58).

5. Comparative Analysis of Plants Growing in Polluted and Clean Areas

A comparative analysis of ornamental trees and shrubs growing in polluted and relatively clean areas shows that the degree of anthropogenic loading of the soil has a direct and complex effect on both the morphological and physiological state of plants. Since plants develop in clean or minimally polluted areas in optimal ecological conditions, normal growth dynamics are observed in their vegetative and generative organs. In such areas, the width of the leaf surface, the amount of chlorophyll, the intensity of shoot formation, and the development of the root system are at a high level.

The soil's richness in humus, balanced distribution of nutrients, and low concentration of heavy metals maintain the physiological processes of plants stably and maximize photosynthetic activity. On the contrary, several stress symptoms are observed in ornamental trees and shrubs growing in polluted areas. As a result of the accumulation of heavy metals in the soil, ion exchange in the root system is disrupted, which limits the absorption of water and minerals. As a result, physiological disorders such as reduced growth, reduced leaf area, chlorosis, and necrosis occur in plants. High concentrations of elements such as lead (Pb), cadmium (Cd), and zinc (Zn) reduce the activity of enzymatic processes, creating metabolic imbalances at the cellular level (Guerriero et al., 2016, p.21)

Comparative analysis shows that while in clean areas the growth of plant biomass is stable and continuous, in polluted areas this indicator significantly decreases. At the same time, differences are also evident in the reproductive development stage; in clean areas the flowering and fruiting process proceeds at a normal rhythm, but in polluted areas this process is either delayed or weakly expressed. From an ecological point of view, although it is observed that some species demonstrate a certain degree of adaptability in polluted areas, this adaptation is not long-term and stable. On the contrary, in clean areas, the genetic potential of plants is fully realized, and the decorative qualities of the species are preserved at the maximum level.

Thus, based on the comparative analysis, it can be concluded that soil pollution is one of the main ecological factors limiting the development of ornamental tree and shrub plants, and this effect is manifested in a complex manner both in morphological changes and in the weakening of physiological processes.

Table 3 presents comparative indicators of plants in polluted and clean areas. As can be seen from the table, as the level of environmental pollution increases, a significant deterioration is observed in all the main morphological and physiological indicators of ornamental trees and shrubs. In clean areas, plants develop in accordance with their genetic potential, demonstrating high decorative and ecological qualities.

Although signs of adaptation are observed in plants in moderately polluted areas, this adaptation is not completely stable and creates certain limitations in the development process. In highly polluted areas, both vegetative and generative development of plants is seriously weakened because of the toxic effects of heavy

metals, which significantly reduce their decorative value (Əliyev, 2021, p. 38). As a result, the data in the table prove that soil pollution is one of the main ecological factors that has a complex negative impact on the development of ornamental plants.

Table 3. Comparative indicators of plants in polluted and clean areas.

Indicators	Clean areas	Moderately polluted areas	Highly polluted areas
Vegetative development	Strong and stable growth	Moderate development	Weak, slow development
Leaf size	Large and normal shape	Relatively small	Small, deformed
Leaf color	Dark green, stable chlorophyll	Light green	Signs of yellowing and chlorosis
Root system development	Deep and widespread	Moderate development	Superficial and weak
Photosynthetic activity	High	Medium	Low
Flowering intensity	Abundant and timely	Partially reduced	Weak and delayed
Fruiting	Normal and productive	Partially reduced	Very weak or absent
Stress symptoms	Not observed	Mild stress symptoms	Severe stress, necrosis, and chlorosis
Biomass growth	High and stable	Medium	Low and unstable

The results of the conducted research show that soil pollution is one of the main ecological factors that has a serious and multifaceted impact on the development of ornamental trees and shrubs. Comparative analyses conducted in areas with different levels of pollution have proven that the accumulation of heavy metals (Pb, Cd, Zn, Cu, Ni) in the soil causes significant changes in both the morphological and physiological indicators of plants.

Ornamental plants growing in clean areas are characterized by high vegetative activity, normal leaf structure, stable chlorophyll content, and a strong root system. In these areas, the soil is rich in humus, and the balanced distribution of nutrients ensures optimal plant development. As a result, the process of biomass growth, flowering, and fruiting proceeds normally and stably.

On the contrary, in polluted areas, plants experience a weakening of development, a decrease in leaf size, physiological disorders such as chlorosis and necrosis, as well as general signs of stress. High concentrations of heavy metals limit the functional activity of the root system, weaken the absorption of nutrients, and reduce photosynthetic activity. This leads to a decrease in the decorative quality of plants.

Based on a comparative analysis, it was determined that as the degree of pollution increases, the adaptation capabilities of plants are limited and their vital activity weakens. Although certain signs of adaptation are observed in moderately polluted zones, this process is not sustainable in highly polluted areas, and sharp declines in plant development occur.

The results of the study also show that the quality of the soil environment plays a decisive role in the development of ornamental plants, and the sustainability of urban greenery is directly related to the ecological state of the soil. Therefore, it is necessary to reduce soil pollution, carry out reclamation measures, and plan green areas on a scientific basis.

In general, the results obtained confirm that ecologically clean soil conditions are one of the main conditions for the healthy development of ornamental trees and shrubs, and the implementation of complex ecological measures in this direction plays an important role in the sustainable development of urban ecosystems.

6. Conclusion

Based on the results of the study, the implementation of the following proposals is considered appropriate to reduce the negative impact of soil pollution on the development of ornamental trees and shrubs and ensure the sustainability of urban ecosystems. First, it is important to take comprehensive measures to reduce the main sources of soil pollution in the urban environment. Limiting emissions from vehicles, applying environmentally friendly technologies in industrial enterprises, and proper waste management can significantly reduce the heavy metal load on the soil.

Expansion and proper planning of urban green systems are of great importance. Creating protective green belts along highways and industrial zones, as well as increasing the area of parks and gardens, can partially prevent the spread of pollutants and improve the microclimate. It is necessary to implement measures for the reclamation and restoration of contaminated soil. Increasing the humus layer, using organic fertilizers, and improving the structure of the soil restore its biological activity, creating more favorable conditions for plant development.

Widespread application of phytoremediation technologies. Planting plant species that can accumulate heavy metals in contaminated areas allows for natural soil purification. This method is considered efficient from both an ecological and economic perspective. It is important to apply a scientific approach to the selection of ornamental plant species. The predominance of pollution-resistant and stress-tolerant species in landscape design increases the viability of plants and ensures the sustainability of green areas.

The establishment of ecological monitoring systems and strengthening of regular control can be indicated. Continuous monitoring of the chemical composition of the soil, heavy metal concentration, and plant development indicators allows for early detection of problems and taking operational measures.

Finally, increasing environmental awareness among the population is also of great importance. Educational measures on environmental protection, care for greenery, and proper waste management can contribute to the formation of an ecological culture and the improvement of the overall ecosystem.

Author's contribution

The sole author is responsible for conceptualizing, collecting, and analyzing data, and writing and editing the manuscript.

Conflict of Interest

The authors declare no conflicts of interest.

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