

**RELATIONSHIP BETWEEN THE CHEMICAL PROPERTIES AND TRACE  
ELEMENT COMPOSITION OF SOILS AND THE BIOECOLOGICAL  
CHARACTERISTICS OF PLANTS IN THE CONTEXT OF URBANIZATION**

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**Abstract:** This study examines the impact of urbanization on the chemical properties and trace element composition (Cu, Zn, Pb) of soils at different site exposures in the Tashkent region. Element content in tree and shrub species was quantified, and its relationship with biological activity and adaptive capacity was assessed. Growth parameters (diameter, height) and reproductive strategies of the species were also analyzed. The results provide insights into plant–soil interactions in urban environments and offer valuable guidance for sustainable landscape planning and management.

**Keywords:** Urbanization, soil chemistry, trace elements, plant ecology, tree and shrub species, pH, adaptation, Tashkent region, monitoring

**Introduction.** Rapid urbanization, driven by population growth, economic expansion, and infrastructure development, is increasingly affecting natural ecological systems, particularly soil and vegetation cover. In urbanized areas, the disruption of ecological stability, increased anthropogenic pressures, emissions from transport, soil compaction, and deficiencies in trace elements directly or indirectly hinder the normal growth and development of plants [5]. Within the framework of this study, soil samples were collected from experimental plots located at different site exposures (410 m, 610 m, 800 m) in the Bostanliq and Kibray districts of the Tashkent region. Their physicochemical properties (pH, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, N-NO<sub>3</sub>, Cu, Zn, Pb, Fe, etc.) were analyzed. The results indicated that soil composition parameters varied significantly depending on site location [10].

The tree and shrub species recorded in these areas included paulownia, catalpa, and poplar at 410 m; ash, red poplar, *Acer negundo* (box elder), and *Acer turkestanicum* at 610 m; and white poplar, paulownia, and catalpa at 800 m. These species exhibited variations in diameter, height, growth rate, and reproductive capacity. In particular, the observed deficiencies in certain trace elements especially Cu and Zn were found to potentially affect key physiological processes such as photosynthesis, enzyme activity, and nitrogen metabolism. This, in turn, can limit the ecological and biological development of plants.

**Materials and Methods.** The number of microorganisms in soil is constantly changing, with fluctuations influenced by anthropogenic, natural, abiotic, and biotic factors [Dedkov V.P. et al., 2009]. Heavy metals such as Cd, Cu, Cr, Ni, Co, Hg, As, and Mn pose significant threats to soil microorganisms [Kurkina M.V. et al., 2017]. The natural self-purification process of soil occurs very slowly, leading to the gradual accumulation of harmful substances, which, over time, become hazardous to humans, animals, and plants. Among the most sensitive indicators of anthropogenic pollution are soil microorganisms, particularly bacteria, actinomycetes, and fungi [Degtyareva I.A. et al., 2011].

The abundance and diversity of soil microorganisms are not constant but depend on the soil's chemical composition, moisture content, temperature, and pH. Household waste contributes to pollution processes, as the chemical components contained in such waste (Bi, Mo, Sb, Cu, Pb, Hg, Ag, As, Sn, Cr, Se, Zn) lead to soil contamination [Dzhivalikyan Kh.S. et al., 2009]. Household waste is considered a potential source of heavy metal (Cd, Pb, Zn, Cu, and Cr) contamination, which can pollute groundwater, soil, and plants [Honghua Liu et al., 2021]. In polluted soils, the concentrations of heavy metals (Cd, Pb, Cu, Ni, Zn) tend to increase [Sokolov M.S. et al., 2016], affecting soil pH, nitrogen-assimilating microorganisms [Feoktistova I.D. et al., 2011], and eventually leading to metal uptake by plants, which may result in plant death.

In summary, this study reviews scientific literature from both domestic and international sources to assess the effects of pollution on the chemical, biological, physicochemical, and microbiological properties of soils, as well as on their fertility indicators. It analyzes changes in heavy metal content, the activity of soil enzymes under pollution stress, soil mechanical composition, and the decline in microbial activity. Furthermore, it considers strategies for preventing these adverse effects and for maintaining, restoring, and enhancing soil fertility to ensure more efficient use of land resources. Special attention is given to components essential for soil productivity, including agrochemical, chemical, and biological properties.

**Results.** This study aims to identify the complex ecological relationships between soils and plants under conditions of urbanization, assess plant adaptability, and develop a scientific basis for sustainable landscape management [4]. Soil samples were collected from experimental plots located in urbanizing areas of the Bostanliq and Kibray districts of the Tashkent region, at different altitudes (410 m, 610 m, and 800 m). The total concentrations of Cu (copper), Pb (lead), and Zn (zinc) in the samples were determined using optical emission spectrometry (SPECTRO GENESIS). Analyses were conducted at depths of 10 cm, 30 cm, and 60 cm to examine variations in heavy metal content by both depth and altitude. The results are summarized in Table 1.

**Table 1. Data from Soil Extracts Obtained via SPECTRO GENESIS Optical Emission Spectrometry (Total forms according to ISO 11460 standard).**

№ t/m	№ Cross-section	Cu	Pb	Zn
		Copper	Lead	Zinc
		%	%	%
1	N 1\10	0,0037	0,0168	0,0170
2	30	0,0039	0,0168	0,0171
3	60	0,0038	0,0163	0,0173
4	N 2\10	0,0035	0,0168	0,0185

5	30	0,0032	0,0162	0,0170
6	60	0,0031	0,0158	0,0171
7	N 3\10	0,0035	0,0119	0,0130
8	30	0,0034	0,0142	0,0334
9	60	0,0034	0,0142	0,0162

**Copper (Cu) Concentration:** Copper is an essential trace element for plants; however, elevated concentrations can negatively affect physiological processes. In this study, Cu content ranged from 0.0031% to 0.0039%, with an average of 0.0035%. These values are below sanitary standards and therefore pose no immediate risk to plants. Nevertheless, for bioaccumulating species (e.g., Paulownia), prolonged exposure may still have adverse effects.

**Lead (Pb) Concentration:** Lead is absorbed only weakly by plants, yet it tends to accumulate in the root zone, harming soil microflora and growth processes. Measured concentrations ranged from 0.0119% to 0.0168%, averaging 0.0153%. This exceeds the permissible limit (MPC) by a factor of five, indicating a serious ecological hazard for urbanized areas.

**Zinc (Zn) Concentration:** Zinc is an essential micronutrient for plant growth and enzymatic processes; however, excessive amounts can have phytotoxic effects. In this study, Zn concentrations ranged from 0.0130% to 0.0334%, with the highest value (0.0334%) recorded at 30 cm depth at the 410m site. Catalpa was found to be sensitive to high Zn levels, which may negatively impact its growth, while species such as white poplar (*Populus alba*) were comparatively more tolerant.

**Impact of Urbanization:** Heavy metals entering the soil through vehicle emissions, construction materials, and industrial dust disrupt soil balance. At the first exposure site in Kibray district (410 m a.s.l.), elevated heavy metal concentrations particularly Pb indicate intensified urbanization pressure in the area.

**Ecological Risks:** **Phytotoxicity** - Adverse effects on plant growth, development, and physiological functions. **Microflora Decline** - Reduced activity of beneficial microorganisms. **Decreased Biogenic Activity** - Lower overall soil fertility. **Bioaccumulation Risk** - Heavy metals may enter the food chain via trees. The role of heavy metals as pollutants in urbanized areas is significant, with lead posing the highest ecological risk. Establishing a permanent monitoring system, reducing pollution sources, and increasing the abundance of phytoremediation-capable species (e.g., Paulownia, white poplar) are essential for maintaining environmental stability.

Table 2.

**Concentrations of elements in plant-available (mobile) forms in the soil**

№	Cross-section №	Concentration of Mobile Element Forms in DTPA Extract (ISO 14870 Standard)								
		B	Cd	Co	Cu	Fe	Pb	Mn	Ni	Zn
		Boron	Cadmium	Cobalt	Copper	Iron	Lead	Manganese	Nickel	Zinc
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
1	1\10	0,430	0,166	0,184	1,208	16,06	0,880	6,06	0,096	0,79

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2	30	0,346	0,224	0,178	1,062	12,88	2,020	5,44	0,096	9,520
3	60	0,162	0,172	0,180	1,056	13,64	0,882	5,48	0,092	1,342
4	2\10	0,322	0,154	0,192	0,444	8,64	0,620	2,18	0,094	0,416
5	30	0,344	0,174	0,216	0,700	10,98	1,398	6,82	0,192	1,114
6	60	0,330	0,172	0,212	0,686	11,16	1,330	6,56	0,190	0,810
7	3\10	0,021	0,166	0,192	0,647	8,98	0,870	3,80	0,158	0,536
8	30	0,003	0,162	0,190	0,656	8,38	0,786	3,10	0,134	0,466
9	60	0,003	0,170	0,186	0,694	9,06	0,790	3,50	0,132	0,564

Based on the analyses conducted at the study site, the mobile forms of heavy metals such as Cu, Pb, and Zn, as well as microelements including B, Cd, Mn, and Fe, were determined using a DTPA extraction method. Their concentrations varied by both depth and altitude, which is significant for assessing soil contamination levels and overall biosecurity status.

1. Lead (Pb) and zinc (Zn) exceeded permissible limits at certain points, increasing the risk of phytotoxicity.
2. Cadmium (Cd), being highly toxic, poses an ecological hazard when present in mobile form in the soil.
3. Boron (B) deficiency, particularly in higher-altitude plots, can inhibit the generative development of plants.
4. **Iron (Fe), manganese (Mn), and copper (Cu) levels were within optimal ranges, ensuring adequate nutrition for plants.**

Under urbanization pressure, some heavy metals tend to accumulate in mobile forms in the soil, adversely affecting plant growth, microbial activity, and overall soil ecological stability. Therefore, planting phytoremediation-capable tree species, implementing permanent monitoring systems, and adopting measures that maintain agro ecological balance are essential.

The moisture content of the soil samples ranged from 1.95 % to 2.92 %, which, for soils located in arid climatic conditions, is considered a relatively low but near-normal level. The proportion of dry matter ranged from 97.08 % to 98.05 %, indicating high density, loamy texture, or a tendency toward slight salinity (Table 3).

**Table 3.**

**Dry Matter and Moisture Content Ratio (Gravimetric Method, ISO 11465)**

№ p/p	Cross-section	Depth, cm	Dry Matter Content, % (Wdm)	Moisture, % (WH <sub>2</sub> O)
1	<b>1</b>	10	97,38	2,62
2		30	97,42	2,58
3		60	97,55	2,45
4	<b>2</b>	10	97,60	2,40
5		30	97,76	2,24
6		60	98,05	1,95
7	<b>3</b>	10	97,08	2,92
8		30	97,61	2,39
9		60	97,91	2,09

Such indicators are characteristic, in particular, of the forest agroecosystems located at the foothills of the Bostanliq district, formed under conditions of natural drying and low precipitation during the summer months.

**Table 4**

**Soil pH and Available Forms of NPK**

№	Layer cm	pH Level		Phosphorus P <sub>2</sub> O <sub>5</sub> , мг/кг	Supply Level	Potassium K <sub>2</sub> O, мг/кг	Supply Level	Nitrogen N-NO <sub>3</sub> , мг/кг	Supply Level
1	10	8,68	Moderately alkaline	6,0	Very low	89,1	Very low	59,2	Moderately high
	30	8,08	Slightly alkaline	5,2	Very low	106,0	Low	211,2	High
	60	7,89	Slightly alkaline	7,6	Very low	106,0	Low	120,4	High
2	10	8,15	Alkaline	17,0	Low	207,1	Moderate	80,2	High

	30	8,28	Alkaline	22,0	Low	187,8	Low	76,4	High
	60	8,39	Alkaline	15,0	Very low	216,7	Moderate	78,1	High
3	10	8,46	Alkaline	6,8	Very low	228,8	Moderate	87,9	High
	30	8,63	Moderately alkaline	5,2	Very low	207,0	Moderate	90,0	High
	60	8,49	Alkaline	4,6	Very low	216,7	Moderate	87,9	High

The soil pH in the study plots ranged from 7.89 to 8.68, with all layers exhibiting an alkaline reaction. Such a reaction is characteristic of carbonate soils and restricts the formation of mobile phosphorus compounds. The phosphorus (P<sub>2</sub>O<sub>5</sub>) content ranged from 4.6 to 22.0 mg/kg, which is considered very low across all layers.

This deficiency may adversely affect the development of plant root systems and generative organs [8].

The potassium (K<sub>2</sub>O) content ranged from 89.1 to 228.8 mg/kg, with some layers classified as low and others as moderately supplied, thus providing partial support for photosynthesis and stress tolerance. Mobile nitrogen (N-NO<sub>3</sub>) ranged from 59.2 to 211.2 mg/kg, indicating layers with both moderate and high nitrogen availability, which creates favorable conditions for vegetative growth (Table 4).

Overall, while the alkaline soils of the Bostanliq and Kibray districts in the Tashkent region contain sufficient nitrogen and potassium, phosphorus deficiency is pronounced. Therefore, the application of phosphorus-based fertilizers, particularly superphosphate, at the initial growth stages is recommended [7].

**Table 5**

**Bio ecology of Tree and Shrub Species in Experimental Sites and Their Ecological Functions in Urbanized Areas**

No	Species	Site Altitude (m)	Diameter, cm	Height, m	Ecological Requirements	Growth Rate	Role in Improving Air Quality
1	Populus alba	410	1.95 ± 0.82	3.5 ± 0.35	Light- and moisture-loving, frost-tolerant	Fast	Large leaf surface effectively traps dust and gases
2	Paulownia tomentosa	410	5.78 ± 0.61	6.94 ± 0.72	Heat- and moisture-loving, prefers light soils	Very fast	Produces high oxygen due to very large leaves

No	Species	Site Altitude (m)	Diameter, cm	Height, m	Ecological Requirements	Growth Rate	Role in Improving Air Quality
3	Catalpa bignonioides	410	3.50 ± 0.55	2.5 ± 0.84	Drought- and frost-tolerant, prefers sunlight	Moderate	Decorative leaves trap dust well; low allergenic potential
4	Populus deltoides	610	4.73 ± 0.41	5.38 ± 0.31	Moisture-loving, prefers fertile soils	Fast	Dense foliage absorbs noise and dust
5	Acer negundo	610	2.87 ± 0.17	2.55 ± 0.42	Adaptable, wind-resistant	Fast	Effective dust trap along streets
6	Robinia pseudoacacia	610	3.02 ± 0.25	3.75 ± 0.58	Drought-tolerant, nitrogen-fixing	Fast	Enriches air with nitrogen and softens the climate
7	R. pseudoacacia 'Sogdiana'	610	3.50 ± 0.65	3.7 ± 0.44	Adapted to regional climate	Fast	Improves soil and air quality via nitrogen fixation
8	Populus alba	800	3.69 ± 0.35	3.24 ± 0.16	Frost-tolerant, slower growth	Moderate	Foliage density helps absorb gases and trap dust
9	Paulownia tomentosa	800	3.30 ± 0.20	3.02 ± 0.19	Slower growth at high altitudes	Moderate	Fast-growing, high oxygen production
10	Catalpa bignonioides	800	3.80 ± 0.35	4.05 ± 0.56	Needs moisture, frost-tolerant	Moderate	Low allergenic risk; reduces airborne dust and toxic gases

In experimental plots located at different altitudes (410 m, 610 m, 800 m) in the Bostanliq and Kibray districts of the Tashkent region, the studied tree species perform important ecological and aesthetic functions under conditions of urbanization. The examined species include (Table 5):

1. **Populus alba (white poplar) – a light-loving, fast-growing, shade-providing tree that captures dust, reduces noise, and purifies the air.**
2. **Paulownia tomentosa (paulownia) – possesses a high capacity for CO<sub>2</sub> absorption, its biomass is used for energy purposes, and it is considered an important species for green architecture.**
3. **Catalpa bignonioides (southern catalpa) – enriches the landscape as a decorative flowering tree, produces no allergens, and creates shaded environments.**
4. **Populus deltoides (eastern cottonwood) – a species capable of producing stable biomass, used in the expansion of suburban ecological zones.**
5. **Acer negundo (box elder) – a fast-growing tree with a high dust-absorbing capacity that helps moderate the urban climate.**
6. **Fraxinus sogdiana (Sogdian ash) – a local endemic species significant for preserving biodiversity and reducing the “heat island” effect.**
7. **Fraxinus pennsylvanica (green ash) – has an erosion-resistant root system, purifies the air, and adapts to various environmental conditions [9].**

These trees and shrubs perform numerous functions in urban environments, including maintaining ecological balance, filtering dust and gas pollutants, regulating the microclimate, creating recreational landscapes, and protecting public health. Therefore, their scientifically grounded selection and placement are crucial factors in establishing sustainable green infrastructure in urbanized areas.

**Conclusion.** Within the framework of this study, soil samples collected from experimental plots located at different exposures (410 m, 610 m, and 800 m above sea level) in the Bostanliq and Kibray districts of the Tashkent region were analyzed for their physicochemical properties (pH, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, N–NO<sub>3</sub>, Cu, Zn, Pb, Fe, etc.). At an altitude of 410 m, paulownia, catalpa, and Lombardy poplar were studied; at 610 m, box elder, eastern cottonwood, green ash, and Sogdian ash; and at 800 m, white poplar, paulownia, and catalpa. These species differed in diameter, height, growth rate, and reproductive capacity [2]. The average copper (Cu) content was 0.0035%, which is below sanitary standards and does not pose a threat to plants. The highest zinc (Zn) concentration, 0.0334%, was recorded at a depth of 30 cm at the 410 m site. Catalpa was found to be sensitive to high Zn levels, which may negatively affect its growth, whereas species such as white poplar showed relatively high tolerance. In Kibray district, the first exposure site (410 m above sea level) exhibited high concentrations of heavy metals, especially lead (Pb), indicating increased urbanization pressure. Pb levels exceeded the maximum permissible concentration (MPC) by a factor of five, representing a serious ecological risk for urbanized areas. Soil pH values ranged from 7.89 to 8.68, indicating an alkaline environment across all layers [1]. Soil moisture content varied between 1.95% and 2.92%, which is considered a relatively low moisture level typical of soils in arid climates.

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