The Effects of Soil-Ecological Factors on the Pb Migration in the Soil of Urban Forest Ecosystem

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Abstract. Leadisone of the most dangerous heavy metals for human. The studies of lead migration in the soil as are significantly important to forecast the transfer factors of lead in ecosystems. The paper represents data of lead concentration in dependence of the soil depth and degrees of anthropogenic impact. The research revealed influence of anthropogenic impact and species of arboreal vegetation on Pb migration in the soil profile. The results of lead concentration positively varyin the soil due to anthropogenic impact from 62.2 mg/kg to 139 mg/kg. The effect of arboreal vegetation species results in the high Pb migration down the soil profile in pine and birch sites and preferable accumulation of Pb in the upper humus horizon in the oak sites.

Keywords: Heavymetals · Lead (Pb) · Soil-ecological parameters · Anthropogenic impact

1 Introduction

Accumulation of heavy metals (HM) in the upper humus layer is reported by many studies [3, 8, 9]. Migration of HM is limited in the lower horizons [1]. The main factors, limiting Pb migration to subsoil are the following: high content of SOM (soil organic matter), the neutral soil pH, the optimal hydrological conditions and redox (RH) conditions [18]. The precipitation of heavy metals and metalloids in the soils of south-eastern district of Moscow on the geochemical barriers has the following regularities: Cd, Cu, and Zn are accumulated on the alkaline barriers; Bi, Sb, As, Cu, Pb, and Zn - on chemisorption barriers; Sb, As, and Pb - on organomineral barriers; and Cd and Cu, on the sorption-sedimentation barriers [10].

In addition to the soil-ecological parameters, the HM migration capacity is determined by the metal. Mercury and zinc are characterized with the highest migration

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ability with soil depth, while the lead and cadmium are less mobile in the soil [4, 5]. Hence concentration of lead is higher in the upper humus layer, closer to the surface of the contaminated soil. However, in highly contaminated soils elevated concentrations of lead at the 40 cm depth are also found [16].

Complexes of lead with humic acids are about 150 times stronger than similar complexes with cadmium [6]. Most of available studies ob HM migration focus on urban or agricultural soils. The data for forest soils is limited and for the Moscow Region such information is lacking. Meanwhile, migration capacity might be different in forest soils, in consequence of deep penetration of the root system.

Arboreal vegetation, characterized with strong and deep root system are able to transport HM into the deeper soil horizons, transforming the soil as a source of toxic substances for many years [13]. The heterogeneity of the soil profile contributes the change of HM availability for plants, increasing risk of HM entering in the food chain [11, 12]. Different micro and macro- element soil composition is the reason of the different HM interaction effect – the synergistic or antagonistic, affects the state of the plants, reducing or increasing their stability [2, 15].

Lead is the one of the most dangerous HM for human. Proceeding through the food chain in the human organism, the excess of lead suppresses the central nervous system, brain function, kidney, muscle; adversely affect the processes of hematopoiesis [7, 17]. The exceptional danger of lead is entering in the food chain and distribution in the urban functioning and suburban forest ecosystems, deteriorating the sanitary functions. The information of lead behavior in the forest experimental station (FES) of Moscow Agricultural Academy soils is practically absent. The research aimed to study the behavior and distribution of lead in the FES of Moscow Agricultural Academy soils.

2 Materials and Methods

Soil samples (HaplicLuvisolaccording to IUSS, 2014, 60 samples) were collected from the experimental plots (the size of 0.5 ha), in the FES located in the northern district of the Moscow city (Russia) on the watershed plateau, relatively far from the influence of industrial facilities and highways (450 to 500 m apart) [13].

The living conditions of the stands are studied as a risk criterion (J) determined by degradation factors. The high value of J shows high anthropogenic impact. In the research 3 sites with different degrees of J are studied. The Ovalue was 2.8 on the verge of disintegration (the Oak, X–XII); 2.5 – weakened condition of plant (the Oak, VII–VIII) and 1.5 – healthy state (the Pine with the birch, IX–XI) [14].

To measure the effect of unregulated recreation, bulk density and soil density were sampled every season from the 0–3 cm, 3–7 cm, and 7–11 cm depth intervals as well as from a full 0–10 cm depth profile. Compaction of the soil layers determines water-air and temperature regimes, redox conditions, and biochemical processes [19]. Lead content in our research was measured by mass-spectrometry.

3 Results and Discussion

Results of the lead distribution in the studied soil profiles are presented at the Figs. 1, 2 and 3. Observed accumulative-eluvial-illuvial character of Pb distribution is characterized by maximum accumulation of the element in the surface layer of soil, and sufficiently deep migration into the soil.

The Pb content correlated with the degree of anthropogenic impact on the surface layer of soil and varied from 62.2 mg/kg (the Oak, X–XII) to 139 mg/kg (the Pine with the birch, IX–XI). Topsoil contents of Pb exceeded subsoil contents 3–10 times. In the illuvial horizon the maximum of the Pb accumulation was observed in the Pine with the birch, IX–XI site. The results revealed significantly dependence of Pb depth migration with the degree of anthropogenic impact.

Lead migration into the soil was positively correlated with soil compaction. At sites of natural forests and remote from the city highways with 0.6–0.8 g/cm^3 soil density content of total Pb (average data) in the illuvial horizon about 2–3 times lower than in sites with increased anthropogenic impacts.

Maximum lead accumulation in the surface layer of the soil indicates the aerial character of contamination. The depth of Pb migration into the lower soil horizons, as well as the scale of distribution in the soil profile is determined by the composition of arboreal vegetation. E.g., in the pine with the birch site Pb content in the B soil horizon is 42 mg. Under the similar conditions with the same distance from the highways under the oak forest, Pb content in the horizon ranges from 18 to 26 mg. Therefore the level of lead pollution at the B horizon of pine with the birch site in 1.6–2.5 times higher

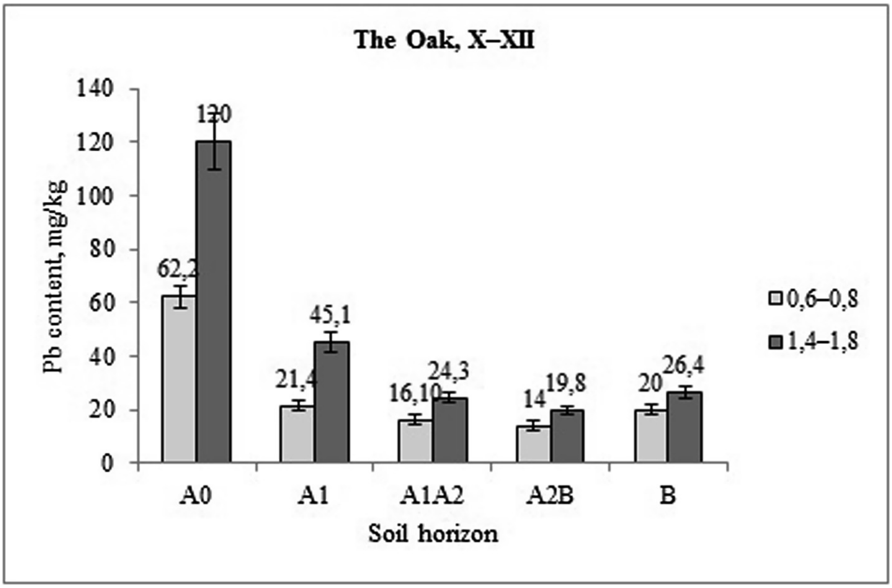

Fig. 1. Distribution of lead in the soil profile with J 2.8.anthropogenic impact degree (verge of disintegration)

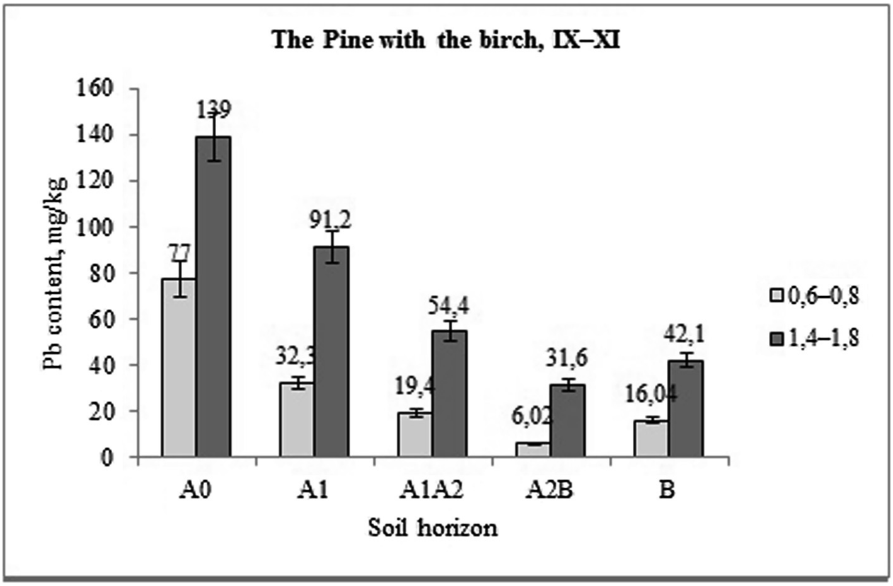

Fig. 2. Distribution of lead in the soil profile with J 2.5.anthropogenic impact degree (weakened condition of plant)

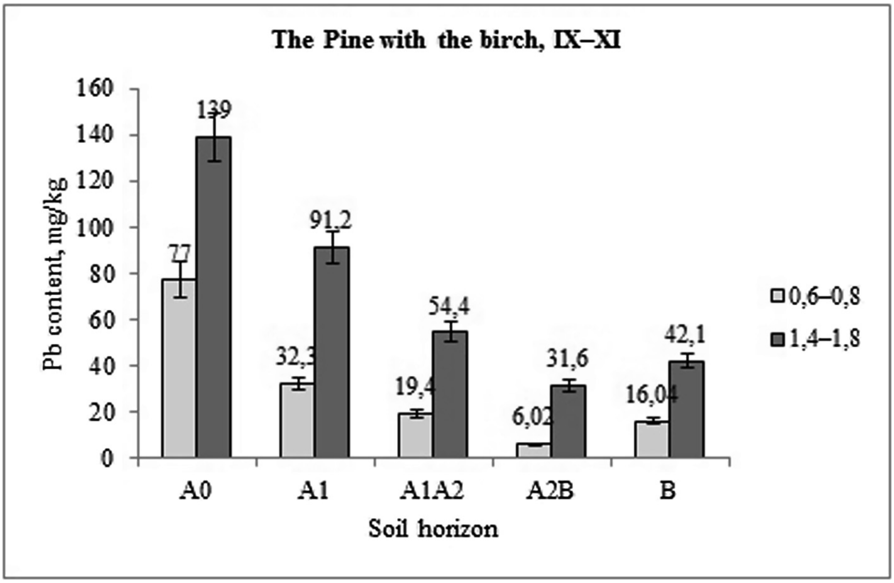

Fig. 3. Distribution of lead in the soil profile with J 1.5.anthropogenic impact degree (healthy state)

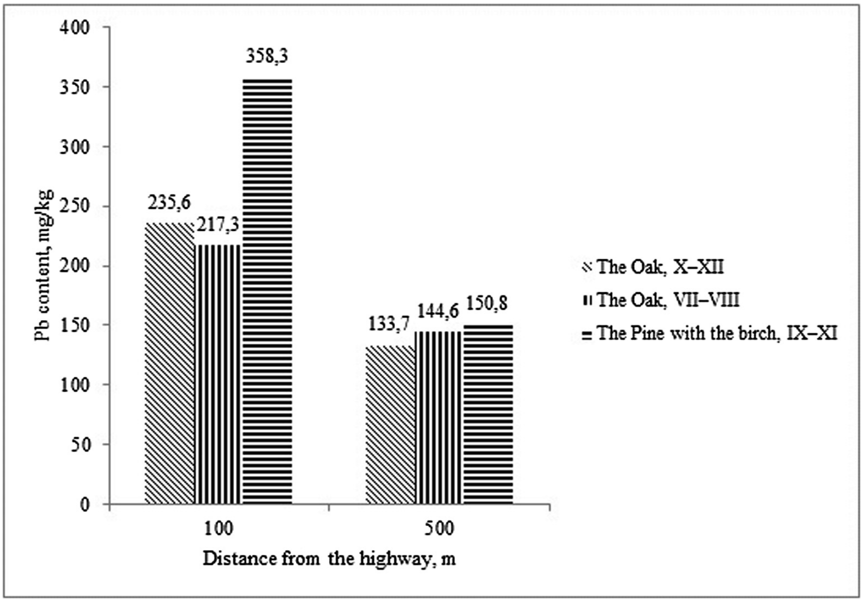

Fig. 4. Accumulation of lead (total content) in the soil profile, depending on the distance from the highway, mg/kg

Table 1. Distribution of the lead in the soil profile under various anthropogenic impacts per 1 cm (1 – Soil density 0.6–0.8 g/cm^3, 2 – Soil density 1.4–1.8 g/cm^3).

Experimental site	Gentichorizon	Depth of sampling, cm		The content of Pb, mg/kg 1 cm layer	
		1	2	1	2
The Oak, X–XII	A_1	0–10	0–4	6.2	30.0
	A_1^1	10–20	4–22	2.1	2.5
	A_1A_2	28–32	30–40	4.0	2.4
	A_2B	45–55	55–65	1.4	2.0
	B	70–80	96–102	2.0	4.4
The Oak, VII–VIII	A_1	0–12	1–6	7.2	22.8
	A_1^1	12–30	6–23	1.5	2.9
	A_1A_2	35–45	25–30	1.5	4.0
	A_2B	55–60	40–50	1.0	1.5
	B	98–104	70–80	2.0	1.8
The Pine with the birch IX–XI	A_1	0–6	0–6	12.8	23.2
	A_1^1	6–24	6–21	1.8	6.0
	A_1A_2	30–40	23–30	1.9	10.8
	A_2B	50–55	40–46	1.2	5.5
	B	76–83	60–70	2.3	4.2

than in the soils of oak forests in increased anthropogenic impact conditions. Perhaps the high content of Pb at the considerable depth of the soil layer under these plantations is due to strong and deep root system, contributes to the more intense movement of Pb in the deeper layers of the soil. In general, the accumulation of lead (total content) in the root layer of soil (to a depth of illuvial horizon B) is significantly higher at sites of the forest, close to the urban thoroughfares (Fig. 4).

In the Table 1 lead distribution down the soil profile under various anthropogenic impacts is showed with the metal concentration expressed per 1 cm layer, associated with different depth of soil genetic horizons.

Per 1 cm root zone Pb content was 1.5–3 times higher in forest areas with high anthropogenic impact (close to urban thoroughfares and in conditions of high recreational load). In this case the maximum values (5.1 mg) of Pb concentration reaches 1 cm root zone soil layer under the pine and birch phytocenosis.

4 Conclusions

The obtained results show significant accumulation of lead in the upper humus layer under increased anthropogenic impact conditions, confirming aerial character of contamination. In the upper humus horizon (A_1 horizon) the accumulative effect is 2–5 times higher in compacted soils compared to less compacted soils. The accumulative effect was 22.8 and 7.2 mg for single-species stands and 23.12 and 12.8 for soils under pine and birch phytocenosis respectively. Pine and birch stands are active conductors of Pb in the soil profile; oak phytocenoses accumulate greater extent of Pb in the upper humus horizon In the upper humus horizon (A_1) observed differences in the accumulative effect are approximately 1.5–2 times in the forest areas with high anthropogenic impact.

The study reveals the possibility of anthropogenic impact influence and species of arboreal vegetation on Pb migration in the soil profile. The results allow forecasting lead mobility in the urban and suburban landscapes and provide an opportunity to develop recommendations for the urban land using of the areas affected by lead contamination.

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