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Lead in soils and pine tree bark (*Pinus sylvestris L.*) from park area exposed to automotive contamination

Ołów w glebach i korze sosny (*Pinus sylvestris L.*) z obszaru parkowego, narażonego na zanieczyszczenia motoryzacyjne

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Abstract

The primary source of soils and plants contamination with heavy metals is rapidly growing traffic. One of the places exposed to harmful effect of vehicle exhaust is Leśny Park Kultury and Wypoczynku in Myślęcinek (LPKiW) near Bydgoszcz. Along LPKiW goes a communication road, which may be the source of environment contamination with heavy metals. The main threat for arable areas and forests is lead (Pb), originating from tetraethyl lead, used until recently as an additive in gasoline.

The aim of the conducted research was to determine the influence of traffic on the content of lead in soils and pine trees bark on the area of LPKiW located in the close vicinity of a busy traffic route.

The research material was collected along the outlet route to A1 highway in the distance of 50 - 75 m from the edge of the road, from 13 representative research points. The content of lead in the research material was determined using ASA method after the mineralization of samples with microwave technique. In surface horizons of the investigated soils the total contents of Pb ranged from 11.71 to 40.58 mg·kg^{-1}, and in subsurface horizons ranged from 8.61 to 9.41 mg·kg^{-1}. The characteristic feature of the investigated soils is the higher accumulation of Pb in surface horizons, which is associated with its absorption by organic matter and clay minerals. The obtained results and literature data as compared with Pb content in reference samples show the influence of vehicles emissions on the Pb content.

Streszczenie

Głównym źródłem zanieczyszczenia metalami ciężkimi gleb oraz roślin jest rozwijający się w bardzo szybkim tempie transport drogowy. Jednym z miejsc narażonym na szkodliwe działanie spalin samochodowych jest Leśny Park Kultury i Wypoczynku w Myślęcinku k/Bydgoszczy. Wzdłuż LPKiW biegnie trasa komunikacyjna, która może być źródłem zanieczyszczenia środowiska metalami ciężkimi. Dla terenów uprawnych i lasów największym zagrożeniem jest ołów (Pb), który pochodzi z czteroetylku ołowiu używanego do niedawna jako domieszka w benzynie.

Podjęte badania miały na celu określenie wpływu transportu samochodowego na zawartość ołowiu w glebach i korze sosnowej, na terenie Leśnego Parku Kultury i Wypoczynku w Myślęcinku, położonym w bezpośrednim sąsiedztwie ruchliwej trasy komunikacyjnej.

Materiał do badań został pobrany wzdłuż trasy wylotowej na autostradę A1, w odległości 50 - 75 metrów od krawędzi jezdni, z 13 reprezentatywnych punktów badawczych. Zawartość ołowiu w materiale badawczym oznaczono metodą ASA po mineralizacji próbek techniką mikrofalową. W poziomach powierzchniowych badanych gleb całkowite zawartości Pb były w zakresie 11.71-40,58 mg·kg^{-1}, a w poziomach podpowierzchniowych - 8.61-9,41mg·kg^{-1}.

Charakterystyczną cechą badanych gleb, jest wyraźnie większa akumulacja Pb w powierzchniowych warstwach gleb, co jest związane z jego absorbowaniem przez substancję organiczną i minerały ilaste. Otrzymane wyniki badań i dane literaturowe oraz porównanie z zawartością ołowiu w próbkach referencyjnych wskazuje na wpływ trasy drogowej na zawartość Pb.

1. INTRODUCTION

Chemical contamination of the environment – a result of economic and technical man activity, cause various types of distribution natural cycle of elements [Czubaszek and Bartoszuk 2011]. Insufficient control of toxic emissions or even total lack of such control causes a negative impact on the environment including forest ecosystem through direct influence on plants or through an indirect impact of accumulated deposit of harmful substances in soil [Marko-Worłowska et al. 2010].

The main source of heavy metals contamination of soils and plants is quickly developing road transport. Street dust occurs commonly and consists of a mixture of wearing road surface and tires, dusts emitted by engines of road vehicles [Adachi i Tainosho

2004]. The emission of heavy metals from various vehicles is not only associated with the combustion of liquid fuels, but is also a result of attrition of tires and asphalt, leakage of oils containing ennobling supplements rich in heavy metals, wearing of linings of brakes, exploitation of tramway and trolleybus infrastructure [Plak et al. 2010; Paukszto et al. 1998].

One of the area exposed to pollution coming from the vehicle exhaust is recreation area (Leśny Park Kultury and Wypoczynku) in Myślęcinek near Bydgoszcz. It is one of the biggest city parks in Poland. Almost half of its area is covered by forest – 470 ha. It has numerous landscape and nature sites as well as recreational and educational areas. From the east side along LPKiW goes a communication road, which may be the source of contamination with heavy metals. Especially dangerous is the contamination of plants with heavy metals, which originates mostly from dusts, smokes, industrial wastes, fertilizers, sewage and vehicle exhausts [Chrzan et al. 2010]. Currently the forest area in Poland covers 29.3% of the whole territory. Forests in our climate – geographical zone are the least distorted natural form. They are an indispensable element of ecological balance and are also the form of land usage, which ensures biological production. The main threat for arable areas and forests is lead (Pb), originating from tetraethyl lead, used until recently as an additive in gasoline. In addition lead is one of the components of street dusts, which are the so called urban elements, originating from public transportation [de Miguel et al. 1997]. In the case of plants, the dusts formed as a result of road traffic, lead to clogging of the stomata, disturbing the photosynthesis process [Zabłocki et al. 1998]. Particularly susceptible to heavy metals contamination are environment elements located in the close vicinity to communication roads within urban clusters.

The aim of the conducted research was to determine the influence of traffic on the content of lead in soils and pine trees bark on the area of LPKiW located in the close vicinity of a busy traffic route.

2. MATERIAL AND METHODS

The research was conducted on the area of Leśny Park Kultury i Wypoczynku in Bydgoszcz (LPKiW) "Myślęcinek". Park covers an area of 830 ha and is located in the northern part of the city within the landscape park Dolina Dolnej Wisły [Szopińska and Sztubacka 2010]. The research material was collected along the outlet route to A1 highway (Fig. 1) in the distance of 50 - 75 m from the edge of the road. The distance between sites of sampling was 100 m. Soil samples were collected from 13 representative sites from two depth: (0-20 cm and 20-40 cm). Samples of pine bark were collected from the same sites from several trees (*Pinus sylvestris* L.). The outermost pieces of bark were sampled from the tree trunks at a height of 1m. Such collected samples were used to make 13 standard samples of pine tree bark. Soil samples after drying were sifted through sieve with ø = 2 mm and the bark samples were pulverized. The analysis of soil material covered: pH measurement with potentiometric method, C-org according to Tiurin method, texture with laser diffraction method using particle size analyzer Malvern Mastersizer 2000 E. The content of lead in soil and bark sample, was determined using ASA method after

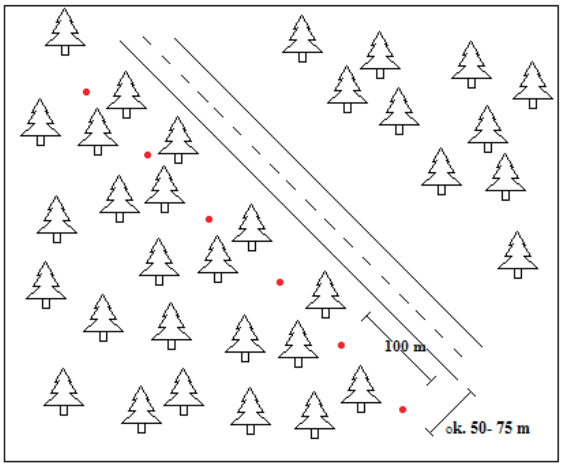

Fig. 1. Soil samples collection scheme

mineralization in concentrated HNO_3 using microwave technique. All analyses were performed in three replicates and results were verified with the use of certified material-TILL3.

3. RESULTS AND DISCUSSION

Soil samples were collected from the research area had varied granulometric composition. The texture analyses allows to classify them as loamy sands or slightly loamy sands (PTG 2009) with the content of coarse fraction (ø 2.0-0.05mm) in the range of 77 to 90% (Table 1). Samples were characterized by acidic or slightly acidic pH. For active acidity pH in surface horizons ranged from 4.55 to 7.06 (Table 1), but in subsurface horizons ranged from 4.73 to 6.02 (Table 1). Exchangeable acidity in surface horizons range 3.78 to 6.93 (Table 1), but in subsurface horizons was in the 4.0—5.46 (Table 1). In all of the soil samples higher pH were observed in surface horizons compared with subsurface horizons. The content of C-org in the investigated soil samples ranged from 4.30 to 48.25 ($g \cdot kg^{1}$) (Table 1). Surface layer contained from 12.77 to 48.25 ($g \cdot kg^{-1}$), but subsurface layer contained from 4.30 to 19.90 ($g \cdot kg^{-1}$).

In surface horizons of the soils the total contents of Pb ranged from 15.99 to 44.41 $mg \cdot kg^{-1}$ and in subsurface horizons from 8.33 to 20.81 $mg \cdot kg^{-1}$ (Table 2).

The characteristic feature of the investigated soils is a significantly higher accumulation of Pb in surface horizons, which is related to its poor migration and adsorption by organic matter and clay minerals and precipitation in form of hardly soluble salts such as carbonate and phosphate. Significantly higher Pb contents in surface horizons also indicate anthropogenic origin (traffic). Moreover, in site no. 1 significant higher than geochemical background level for Pb was observed, which may be the result of a close location to snow deposit site, which is being removed from the area of the city, the tram loop and the parking place. Particularly susceptible to heavy metals contamination are terrains situated near the heavily traffic roads. Ciećko et al. [1998] pointed out that the highest level of heavy metals is observed within 70 m from the edge of the road and beyond the distance

Table 1. Texture and some chemical properties of the studied soils

No	Depth [cm]	Texture [%]			C- org. [g·kg^{-1}]	pH	
		2,0-0,05	0,05-0,002	<0,002		H_2O	KCl
1	0-20	90	10	0	48.2	5,70	4,88
	20-40	87	12	1	11.1	5,17	4,44
2	0-20	81	18	1	20.5	4,96	4,05
	20-40	81	18	1	19.9	4,74	4,04
3	0-20	83	16	1	14.1	5,15	4,11
	20-40	90	9	1	4.3	5,15	4,64
4	0-20	77	13	0	30.4	5,08	4,19
	20-40	93	7	0	7.7	4,93	4,18
5	0-20	87	12	1	17.1	5,18	4,33
	20-40	84	15	1	11.0	5,19	4,37
6	0-20	85	14	1	27.8	4,92	3,99
	20-40	86	13	1	6.7	4,95	4,39
7	0-20	82	17	1	32.8	6,33	5,59
	20-40	84	15	1	10.9	5,51	4,55
8	0-20	88	11	1	16.2	5,20	4,42
	20-40	81	17	2	11.4	5,63	4,67
9	0-20	82	15	3	17.9	5,03	4,24
	20-40	83	14	3	14.3	4,90	4,3
10	0-20	84	15	1	32.2	4,55	3,78
	20-40	82	17	1	17.8	4,73	4,02
11	0-20	82	16	1	18.9	7,06	6,83
	20-40	87	12	1	18.9	5,37	4,44
12	0-20	83	15	1	13.3	6,17	5,78
	20-40	82	16	2	13.3	6,02	5,46
13	0-20	84	15	1	12.8	4,90	4,07
	20-40	83	16	1	7.4	5,19	4,17

of 150 m their content is accepted for the area not exposed to vehicles contamination, which is confirmed by the conducted study. The factor that also affect such elevated heavy metals content is high level of air dust. The particles of dust are carriers of heavy metals as a result of adsorption forces and interactions between dust particles surface and lead [Baran et al. 2007]. As particularly susceptible to contamination, originated from the traffic, are forest ecosystems on which soil contamination has a significant impact. Road contamination as a stress factor, may negatively affects vitality, productivity and species composition of forests. Therefore the analysis of Pb content in soils is one of the most important indicators of anthropoid pressure and may reflect air pollution and the impact of processes occurring in soils near the roads with heavier traffic on forest area [Kabała et al. 2014]. The total content of Pb in the investigated pine tree bark samples is quite diverse and ranges from 5.5 mg·kg^{-1} to 38,0 mg·kg^{-1} (Table 2). The total content of Pb in the investigated samples allows to classify the investigated trees to plants with critical Pb content, but in several samples toxic level were detected (Table 2). The obtained results and the literature data allow

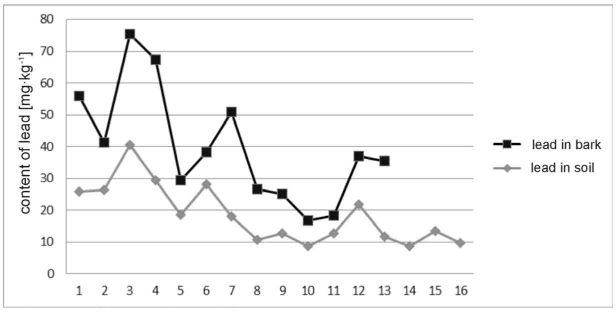

Fig. 2. Total content of Pb in soil and pine bark

to classify the investigated plants as contaminated with lead. Elevated level contents of this element may be related to its emission by vehicles and accumulated in plants tissues. Part of lead contained in bark may have been taken from soil, on which may indicate significantly higher contents of Pb in soil and bark samples from the same research point (Fig. 2). However, lead is a metal hardly mobile and its uptake by plants from soil is not large, therefore it may be presumed that its content in the bark is

Table 2. Total content of Pb in soil and pine bark

No	Depth	Lead in soil [mg·kg^{-1}]	Lead in bark [mg·kg^{-1}]
1	0-20	44.41	30,0
	20-40	13.02	
2	0-20	20.83	14,75
	20-40	20.81	
3	0-20	23.97	34,95
	20-40	8.33	
4	0-20	29.64	38,0
	20-40	9.91	
5	0-20	18.16	10,75
	20-40	13.36	
6	0-20	24.28	10,0
	20-40	10.82	
7	0-20	23.27	32,9
	20-40	13.87	
8	0-20	15.99	16,0
	20-40	11.91	
9	0-20	20.31	12,2
	20-40	16.44	
10	0-20	22.11	8,0
	20-40	10.32	
11	0-20	25.45	5,5
	20-40	11.67	
12	0-20	24.37	15,25
	20-40	12.78	
13	0-20	27.14	23,85
	20-40	14.87	

related also to the presence of this element in the atmosphere. Natural content of Pb in plants is within the range of 3 mg·kg^{-1} to 10 mg·kg^{-1} [Greszta and Panek 1999]. The value considered toxic for plants is 30-38.0 mg·kg^{-1} [Kabata-Pendias and Pendias 2010, 1998]. The total content equal to 19 mg·kg^{-1} is given as critical and total content equal to 43 mg·kg^{-1} may cause dieback of conifers [Dmuchowski and Bytnerowicz 1995]. The total content of Pb in the investigated samples allows to classify the investigated trees to plants with critical Pb content, but in several samples toxic level were detected. Elevated contents of this element may be related to its emission by vehicles and accumulated in plants tissues. The bark traps airborne pollutants directly from atmosphere and absorbs washed dry deposits from the surface of the tree crown. Trees can also collect suspended pollutants due to the wind erosion of soil particles. The content of pollutants in tree bark correlates well with the concentration of these pollutants in the atmosphere. Thus, bark has been used for bioindicating anthropogenic atmospheric contamination [Guéguen et al. 2011].

4. CONCLUSION

Analyzed soils, acidic or slightly acidic loamy sands, contain from 4.30 to 48.25 g·kg^{-1} of C-org. In the surface horizon, the total contents of Pb ranged from 15.99 to 44.41 mg·kg^{-1} and in subsurface horizons from 8.33 to 20.81 mg·kg^{-1}, which indicate elevated content of Pb in several research sites. The total content of lead in the pine tree bark exceeded natural concentration of this element in plants and reached the toxic level. The results of the investigation show the accumulation of the metal indicating contamination with lead. Thus, the negative impact of the traffic on the content of heavy metal in pine tree bark from LPKiW in Myślęcinek and in some soil samples, lead to a conclusion that this area should be monitored. Furthermore, the study confirmed the usefulness of pine tree bark for biomonitoring of air due to its porous structure.

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