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Heavy Metal (Cd, Cr, Cu, Ni, Pb, Zn) Concentrations in Spruce *Picea Abies* L. along the Roads of Various Traffic Density in the Podhale Region, Southern Poland**

1. Introduction

Road traffic plays an important role as a source of air, soil and plant pollution. Numerous substances emitted by road vehicles are qualified as toxic [28, 30]. Traffic emissions, in general, are regarded as the likely source of such elements as: Ba, Ca, Cd, Co, Cr, Cu, Fe, Mo, Ni, Pb, Pd, Pt, Rh, Sb, V and Zn [5, 10, 12, 31]. In particular, heavy metals such as Cd, Cu, Pb, Zn are among various toxic substances deriving from vehicle emissions [28]. Cadmium, Cr, Cu, Pb, Ni and Zn come, among others, from Diesel engines [29], Zn – from tire abrasion [29], platinum group elements – from catalyst [5, 31], Cd, Cr, Cu, Pb, Zn – from break abrasion [13, 23, 29], Cd, Ni and mostly zinc from lubricants [13].

Numerous papers on the topic of roadside ecosystems concern soil pollution. Relatively lower number of papers deal with roadside vegetation, but mostly with crops, consumption plants, forage, etc. [3, 4, 6, 7, 18, 31]. Mosses, lichens and some other plant species are regarded as very sensitive bioindicators of atmospheric pollution [1, 22]. Vascular plants are frequently used for biomonitoring, though they usually accumulate heavy metals to the less extend. Various plant species, including coniferous trees: pine *Pinus sylvestris* [17, 24, 27] and spruce *Picea abies* [2, 9, 14–16, 20, 25, 26] are recommended as bioindicators of traffic pollution. Spruce *Picea abies* L., because of its widespread distribution and ability to tolerate various conditions is regarded as a good bioindicator of environmental pollution especially in mountain region in Southern Poland [8, 19, 20].

The aim of the paper was to determine influence of traffic density on heavy metal (Cr, Cd, Cu, Ni, Pb, Zn) concentrations using two year old needles of spruce *Picea abies L.* collected along the roads of various traffic volumen in the Podhale region, Southern Poland.

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2. Material and Methods

The species *Picea abies* L. was selected as road pollution indicators due to widespread occurance across the study area. Needles of spruce were recommended as bioindicator of Poland's mountain forests ecosystems [8]. The samples of two years old needles of *Picea abies L.* were collected along two roads of various traffic volume: main road no. 95 Kraków – Zakopane of heavy traffic density between Chabówka and Nowy Targ (road I) and local district road of low traffic density no. K1644 (25410) connecting two villages Łopuszna and Dursztyn (road II, Fig 1). Road selection in the Podhale region was based on variety of traffic density. Available data on traffic volume were taken from Generalna Dyrekcja Dróg Krajowych i Autostrad, Kraków (http://www.krakow.gddkia.gov.pl).

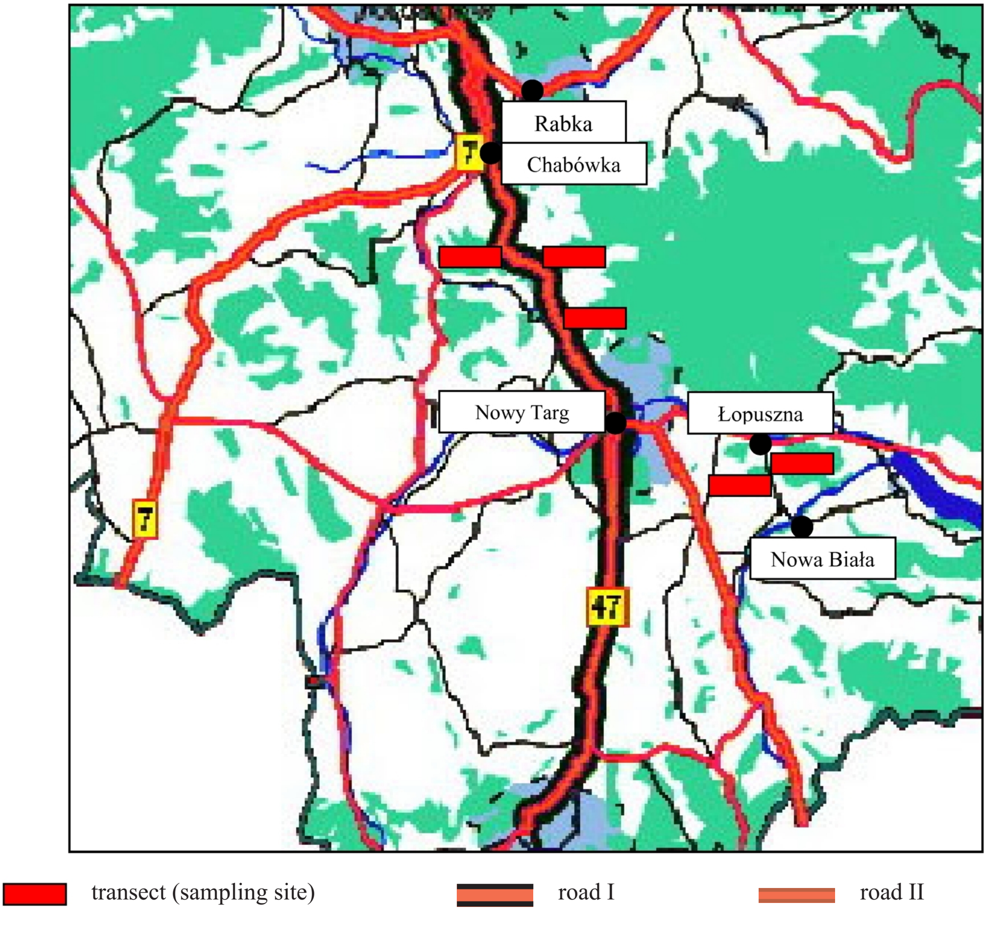

Fig. 1. Roads location

Data for section Chabówka – Nowy Targ were not available and data for nearest counting stations: Rabka – Chabówka (10 959 vehicles per day) and Nowy Targ – Szaflary (13 518 vehicles per day) were taken and calculated as average. Also there are no data for the road section: Łopuszna – Nowa Biała and value of 1584 vehicles per day comes from own observations. The samples were collected along five transects situated vertically to the roads. Each transect consisted of four sampling sites, located at the following distances from the road: 5 m, 10 m, 50 m and 100 m. Samples were taken from twenty sites. Each sample consisted of plant material taken at least from five individuals per site. Plant samples were collected at the height of 1 m above the ground. Sampling was carried out in October 2006.

Three transects were located at the road I Chabówka – Nowy Targ and two of them at the road II Łopuszna – Nowa Biała, The highest location of sampling transect was: 738 m above sea level (road I Chabówka – Nowy Targ) and the lowest one 592 m above sea level (road II Łopuszna – Nowa Biała). Landscape configuration of selected transects varied from descending slopes (two transects along the road I) and flat area (one transect along the road I and two transects along the road II). All transects were located in the mountain spruce forests.

Dried at 60°C for 48 h and ground homogeneous plant material (1 g) was mineralised hot in 20 ml mixture of perchloric acid $HClO_4$ and nitric acid HNO_3 in the ratio 1:4. The samples were mineralised using Kjeldahl digestion system. The obtained digestive was evaporated and diluted with distilled water to the volume of 50 ml and filtered. Total concentrations of Cd, Cr, Cu, Ni, Pb, and Zn were determined in obtained solutions by the atomic adsorption spectrofotometry (AAS) using spectrophotometer Hitachi Z-8200.

3. Results and Discussion

Concentrations of trace metals in spruce needles varied widely depending on distance from the road and traffic density. In respect to the studied metals, zinc was accumulated in the highest and cadmium in the lowest concentrations, regardless the distance from the road and traffic density.

Concentrations of all elements, with exception of cadmium and to some extend of zinc, descended according to the increasing distances from the both roads regardless road traffic density (Tab. 1). Generally the highest concentrations of Cr, Cu, Ni and Pb were stated at the distances of 5 m from the heavily frequented road Chabówka – Nowy Targ (road I) as well as from the road of low traffic density Łopuszna – Nowa Biała: 2.5 ± 0.2 and 2.9 ± 0.6 μg Cr/g; 10.1 ± 1.3 and 6.1 ± 1.3 Cu/g; 2.9 ± 0.2 and 1.1 ± 1.3 μg Ni/g; 2.4 ± 0.6 and 1.0 ± 0.3 μg Pb/g, respectively. The lowest concentrations were observed at the distance 100 m along the both mentioned roads.

Table 1. Heavy metal concentrations in spruce *Picea abies* L. [μg/g d.w.], mean values ($\overline{x}$) and standard deviation (SD)

Location	Distance from the road [m]	Number of the samples	Mean values [μg/g d.w.] ±SD					
			Cd	Cr	Cu	Ni	Pb	Zn
Chabówka – Nowy Targ	5	15	0.2 ± 0.1	2.5 ± 0.2	10.1 ± 1.3	2.9 ± 0.2	2.4 ± 0.6	22.6 ± 5.8
	10	18	1.0 ± 0.1	1.4 ± 0.2	8.4 ± 0.9	1.8 ± 0.3	1.0 ± 0.3	20.8 ± 2.5
	50	22	0.9 ± 0.4	0.8 ± 0.1	5.3 ± 0.2	1.6 ± 0.2	0.6 ± 0.4	10.5 ± 1.7
	100	28	1.2 ± 0.2	0.3 ± 0.1	1.3 ± 0.3	1.2 ± 0.1	0.2 ± 0.3	19.8 ± 1.2
Łopuszna – Nowa Biała	5	16	0.4 ± 0.1	2.9 ± 0.6	6.1 ± 1.3	1.1 ± 0.2	1.0 ± 0.3	30.1 ± 4.2
	10	19	0.7 ± 0.2	1.3 ± 0.4	3.6 ± 0.4	0.9± 0.2	0.8 ± 0.2	11.9 ± 3.0
	50	24	0.5 ± 0.1	0.9 ± 0.2	2.6 ± 0.5	0.6 ± 0.1	0.5 ± 0.2	21.5 ± 1.4
	100	32	0.9 ± 0.3	0.4 ± 0.2	1.2 ± 0.2	0.4 ± 0.1	0.2 ± 0.1	6.8 ± 0.9

d.w. – dry weight

Concentrations of cadmium were very low and did not show concentration tendency with increasing distance from the road and therefore it was difficult to consider this metal as deriving from road emissions. The highest level of cadmium was observed at the distance of 100 m from the road Chabówka – Nowy Targ (1.2 μg/g). The same tendency was observed in previous studies for dandelion *Taraxacum officinale* along the road Kraków – Zakopane [11] and also was reported by Zechmeister *et al.* [30] in case of cadmium content in moss species along the roads in the Alps in South Western Austria. Increasing concentrations of cadmium with growing distance from the road indicate that traffic pollution can not be regarded as a major source of that metal in the environment.

Traffic volume influenced metal concentrations in spruce *Picea abies* L. Basically higher concentrations of trace metals were observed in plants sampled along the road Chabówka – Nowy Targ than along the local road of low traffic density. Differences in metal concentrations were presented by concentration coefficients, calculated as quotient of metal concentrations at the same distances from the roads I and II (Tab. 2).

Table 2. Metal concentration coefficients at different distances from the road

Distance [m]	Metal coefficient					
	Cd	Cr	Cu	Ni	Pb	Zn
5	0.5	0.9	1.7	2.6	2.4	0.8
10	1.4	1.1	2.3	2.0	1.3	1.7
50	1.8	0.9	2.0	2.7	1.2	0.5
100	1.3	0.9	1.1	3.0	1.0	2.9

The highest differences in metal concentrations between two road, expressed by concentration coefficient, were observed in case of Pb and Cu up to 10 m from the road and also in case of Ni and Zn at the distance of 100 m, what may indicate that only Pb and Cu come mainly from traffic pollution and their concentrations depend on vehicle density. It is not quite clear that traffic volume influence Zn, Cd and Ni concentration in spruce *Picea abies,* because the highest concentration of above mentioned metals were stated at the distance of 100 m from the road. Exceptionally high concentrations of Zn at the distance of 5 m (30.1 mg/kg) and Cd at the distance 100 m from the road of low traffic density can be explaned by other local emission sources than traffic pollution. Spatial distribution of Cr, Cu, Pb along the roads indicate that traffic emissions are the most probable source of those metals, what remains in accordance with other studies [23, 30].

Two years old needles of spruce *Picea abies* L. accumulated considerably low amounts of metals in comparison with *Pleurozium schreberi* and even with dandelion *Taraxacum officinale,* collected in the same sites along the road Chabówka – Nowy Targ [11, 21], nevertheless metal concentrations accumulated by this species reflect spatial differences in the vicinity of the roads in the Podhale region, what was also found by Józefko and Panek [20] in their previous studies. Thought spruce *Picea abies* L. displays lower ability to accumulate trace metals than other plant species studied, but because of its widespread distribution across Poland, especially in mountain ecosystems may be the useful bioindicator of metal pollution in Southern Poland.

4. Conclusions

The obtained results indicate that road traffic is a major source of heavy metals: Cr, Cu and Pb in spruce *Picea abies* L. along the roads of various traffic density. Distance from the road influenced spatial distribution of those metal concentrations. Higher levels of metals, with exception of Zn, were stated for the heavily frequented road Chabówka – Nowy Targ than along the local road of low traffic density Łopuszna – Nowa Biała. *Picea abies* L. occurs to be an useful bioindicator of environmental pollution because of widespread distribution across the studied area.

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