J. Elem. s. 119–128 DOI: 10.5601/jelem.2014.19.1.591

LEAD AND CADMIUM CONTENT IN SOME GRASSES ALONG EXPRESSWAY AREAS

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Abstract

Due to intense road traffic, plants are exposed to stress factors, mainly fumes, dust from rubber grinding and clutch dust. Among numerous chemicals deposited near roads, heavy metals, e.g. lead and cadmium, are the most dangerous. The aim of the study was to evaluate the effect of distance from a road on the content of lead and cadmium in some grasses and their influence on health and safety of livestock. The following grasses were collected from grasslands located near the S2, an international road running near Siedlce, a town in the east of Poland: orchard grass, meadow foxtail and tall oat grass. The plant material was taken 1 m, 5 m, and 10 m from a roadside ditch at sites approximately distant 100 m from one another. From individual batches, 5-7 samples were made for each species of plants and from each distance from the road edge. The content of lead and cadmium was estimated using the ASA method. The accumulation of lead and cadmium in grass growing along the expressway depended on the grass species and distance from the road. Regardless of the grass species, the highest level of heavy metals was found in the plant material collected 5 m from the road, and an average lead content was nearly 17-fold higher than that of cadmium. Irrespective of the distance from the road, lead was more readily accumulated in tall oat grass and meadow foxtail, whereas cadmium was mainly absorbed by orchard grass. The grass species recommended for sowing on soil contaminated with lead is orchard grass, but meadow foxtail is a better choice to sow on land polluted by cadmium.

Keywords: lead, cadmium, grasses, roadside strip.

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ZAWARTOŚĆ OŁOWIU I KADMU W WYBRANYCH GATUNKACH TRAW ROSNĄCYCH WZDŁUŻ DROGI SZYBKIEGO RUCHU

Abstrakt

Eksploatacja dróg powoduje narażenie roślin na czynniki stresogenne. Są to głównie składniki spalin oraz pyły powstające przy ścieraniu opon, tarcz sprzęgła oraz innych elementów ciernych pojazdów. Spośród wielu substancji chemicznych deponowanych obok drogi, największy wpływ na środowisko mają metale ciężkie, a wśród nich ołów i kadm. Celem badań była ocena wpływu odległości od drogi na zawartość ołowiu i kadmu w wybranych gatunkach traw w kontekście bezpieczeństwa sanitarnego w przypadkach spożycia przez zwierzęta hodowlane. Materiał roślinny w formie części nadziemnych pobrano w sierpniu 2011 r. wzdłuż 9 km odcinka trasy szybkiego ruchu S2 (Obwodnica Siedlec). Próbki pobierano losowo w odległości 1, 5, 10 i 15 m od skraju jezdni, po obu stronach drogi, na odcinkach długości ok. 100 m. Z pobranych próbek jednostkowych wykonano 5-7 próbek dla każdego gatunku roślin i każdej odległości od skraju jezdni. Zawartość ołowiu i kadmu oznaczono metodą AAS z użyciem absorcjometru Varian Spectra AA20. Kumulacja ołowiu i kadmu przez trawy rosnące wzdłuż drogi szybkiego ruchu zależała zarówno od gatunku trawy, jak i odległości od trasy. Niezależnie od badanego gatunku trawy, najwięcej oznaczonych metali ciężkich stwierdzono w materiale roślinnym zebranym 5 m od drogi, a średnia zawartość ołowiu była prawie 17 razy wyższa niż kadmu. Niezależnie od odległości od drogi szybkiego ruchu, ołów w największym stopniu był kumulowany przez wyczyniec łąkowy i rajgras wyniosły, a kadm głównie przez kupkówkę pospolitą. Gatunkiem trawy zalecanym do obsiewu terenów skażonych ołowiem jest kupkówka pospolita, a kadmem – wyczyniec łąkowy.

Słowa kluczowe: ołów, kadm, trawy, pasy przydrożne.

INTRODUCTION

Grasses are typical groundcovers in areas adjacent to a roadway. Roadside sward is composed of grasses which are most frequently sown there, dicotyledonous herbs and weeds. They are subject to continuous stress factors caused by traffic. Traffic-related metals originate mainly from combustion of heated fuel, e.g., Pb, lubricating motor oil, vehicle tire wear and brake pads, e. g., Cd, Mn, Zn, Cu (Sadiq et al. 1989, Olajire, Ayodele 1997, Panayotova 2000). Motor vehicles release a number of pollutants into the environment. Roadsides receive considerable amounts of these traffic-generated pollutants (Sutherland, Tack 2000). Also, substances used to maintain roads passable in winter are a cause of pollution. Among many chemical substances deposited near roads there are heavy metals, including lead and cadmium, which have the strongest impact on the environment. Large quantities of heavy metals deposited in soil and those emitted by exhaust fumes lead to their increase in plants growing along roads. However, their actual accumulation in plants is mainly connected with the bioaccumulation potential, which is species-specific. The capacity of different plant species to accumulate metals, which reflects the environmental contamination, has been investigated by many researchers (Gondek, Filipek-Mazur 2006, Jankowska et al. 2007, Królak 2001, Mazur et al. 2007, Naszradi et al. 2004, Wieczorek et al. 2004).

On both sides of a highway there are often agricultural lands and livestock can be seen grazing (Filipek-Mazur et al. 2007, Olajire, Ayodele 1997, Garcia, Milan 1998). Thus, the aim of this study was to evaluate the effect of distance from a road on the content of lead and cadmium in some grasses and their influence on livestock's health.

MATERIAL AND METHODS

The plant material consisting of aerial grass biomass was taken in August 2011 along a 9-km section of the S2 Road (a bypass around Siedlce) – Figure 1. The whole road connects Cork in Ireland with Omsk in Russia and is therefore one of the most important transporation routes in Europe. The Polish section is called the S2. The area where samples were collected lies in the Province of Mazowsze (*województwo mazowieckie*), which is located in East-Central Poland, about 80 km east of Warsaw.

The following grasses were collected from grasslands located near the international road S2 near Siedlce: orchard grass, meadow foxtail and tall oat grass. The plant material was taken from the distance of 1 m, 5 m and 10 m from a wayside ditch, at approximately 100-meter intervals. Each batch served to make 5 to 7 samples of each plant species and each distance from the edge of the road.

First, the collected plant samples were dried at 105°C; next, the weighed samples were dry-mineralized at 450°C for over 24 h, and then solutions in 10% HCL were prepared. The concentrations of lead and cadmium in the

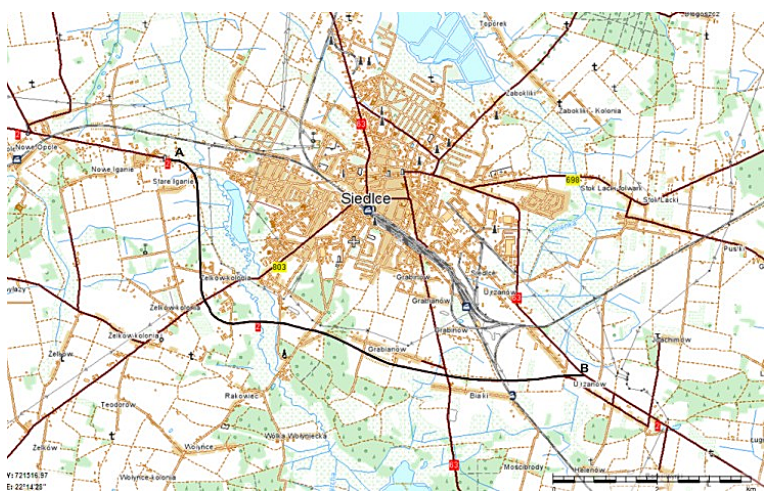

Fig.1. Map of sampling sites along the S2 Road

solutions was estimated using the ASA method. The results were statistically analyzed using Statistica 6.0. A detailed comparison between the mean values was conducted via the Tukey's test at $p \leq 0.05$. When the effect of the quantitative factor (distance) was found, orthogonal contrasts were used to estimate the character of the effect. Correlation coefficients were calculated according to the Sperman's rank between the content of lead and cadmium as well as between their harvest place.

RESULTS AND DISCUSION

The content of lead and cadmium in the grass species depended on both the type of grass and the distance from the road. Among the examined grass species, the highest level of lead was found in meadow foxtail (5.18 mg g^{-1}) growing within 15 m from road. In both orchard grass and tall oat grass the largest lead accumulation occurred within 5 m from the road, where it reached 4.72 and 5.01 mg kg^{-1}, respectively. In both of these grass species, as the distance from the road grew, the accumulation of lead steadily declined, down to 2.20 at 10 m and 1.64 mg kg^{-1} at 15 m from the road. The results were compared to the limit imposed on the lead content in feeds for ruminants, which is 10 mg kg^{-1} d.m. according to RENGEL (2004). The results suggest that the tested grasses can be used in animal nutrition. It should also be observed that the analyzed species of grasses looked healthy because their content of lead had not reached the toxic level (GORALACH, GAMBUŚ 2000). Plant poisoning with lead, according to WEGLARZ (2007), may occur when the Pb content is more than 15 mg kg^{-1} of dry matter. This concentration of lead can impair the process of photosynthesis by reducing chlorophyll biosynthesis (BAYCU et al. 2003). With regard to Pb, the roadside concentration of this element found in our study was much lower than reported by other researchers (FILIPEK-MAZUR et al. 2007, GARCIA, MILAN 1998). It is worth noting that the lead content in these grass species and at a distance of 1 m from the road was almost half of that found at 5 m distance from the road. SWAILEH et al. (2004) found average metal concentrations in *Inula viscose* leaves distinctly below the range of metal concentrations in plant leaves considered phytotoxic. However, the concentrations of Pb in the roadside samples of *I. viscose* leaves were higher than those reported in leaves of the same plant from a control site (SWAILEH et al. 2001).

Regardless of the grass type, the highest lead content was found in the plant material taken from the 5-meter distance from the road (4.35 mg kg^{-1}). This value differed significantly from the lead content in the plant material at the other distances from the road. Likewise, in his study, SWAILEH et al. (2004) demonstrated that lead gradually decreased from a 0-m to a 15-m distance. Thereafter, no further significant decrease was observed.

In contrast to soil, no sharp decrease in the concentration of any metal in plants was observed. CHRONOPOULOS et al. (1997) studied the reduction of Pb concentrations from a periphery to the interior (60 m) of some parks in Athens, Greece. Lead contamination was found up to about 40 m, beyond which little change in Pb concentration was observed in leaves of *N. oleander* and *Pittosporum sinensis.* OTHMAN et al. (1997) observed longer distances for the lead pollution coverage along roads of the city of Damascus. They recommended that vegetables should be planted at least 200 m away from a roadside. According to the same reference, most lead particles emitted by vehicles are deposited on roadside soils (0-5 m), but some can be carried by winds over a long distance.

Another important metal in plants growing in areas adjacent to roads is cadmium. FRENER (2001) claims that a critical cadmium content in plants which precludes their use for consumption should be less than 0.15 mg kg^{-1} d.m., but it should come to ≤ 0.5 mg kg^{-1} d.m. for feeding. The studied plant material did not exceed this value.

Among the examined grass species, most Cd was bio-accumulated by cocksfoot at a 5-metere distance from the road (0.45 mg kg^{-1}). At a larger distance from the road, the cadmium content steadily decreased to 0.15 mg kg^{-1} in plants grown at a distance of 15 m from the road. As in the case of lead, the cadmium content in cocksfoot growing within 1 m from the road was almost 50% lower than in plants at a 5 m distance. In turn, tall oat grass and meadow foxtail accumulated the highest levels of cadmium one meter form the road (0.19 mg $kg^{-1}$and 0.18 mg kg^{-1}). Regardless of the grass type, the lowest cadmium values were found in the plant material collected from a 15-m distance from the road (mean value 0.12 mg kg^{-1}). This content was significantly different from the heavy metal content found in the plant material taken from the other (closer) distances from the expressway.

As in the case of lead, the highest level of cadmium was accumulated by plants at a distance of 5 m from the road (0.26 mg kg^{-1}). DIATTA et al. (2003) states that concentrations of metals in plant samples collected at different distances from a road edge exhibited statistically significant negative relationships with the distance from the road edge, except for Cd.

The results contained in Table 2 lead to the conclusion that in areas contaminated with lead, cocksfoot is a suitable species for sowing because the maximum amount of this heavy metal was found only in tall oat grass and meadow foxtail. With regard to the accumulation of cadmium by those three grass species, it was demonstrated that the most recommended species for such areas is meadow foxtail. This species, regardless of the distance from the roadway, did not reach the maximum content of cadmium at different distances from the road. According to SWAILEH et al. (2004) and NABULU et al. (2006), using plants to identify the roadside pollution seems to be a better solution than using soil concentrations of pollutants. In addition, plants reflect amounts of metals that are biologically available to plants.

It is very difficult to compare literature data concerning contamination levels with heavy metals in plants near highways is very difficult (VIARD et al. 2004). The levels of cadmium extracted from the plant material analysed in our study were lower than observed by many authors in *Graminaceae* (RODRIGUEZ et al.1982 or HO and TAI 1988), who studied *Chenchrus echinatus, Sarghum halopense, Paspalum paniculatum* or *Stipia ichu*. Nevertheless, they are similar to the values achieved in recent studies on tobacco leaves or herb leaves and vegetables (OTHMAN et al. 1997). Levels of cadmium were lower than those observed in earlier studies of HO and TAI (1988), although they were comparable to those observed by many other authors (CIEPIELA et al. 2009, GARCIA, MILAN 1998, SEGURA-MUNOZ et al. 2004, PANAYOTOVA 2000, OKUNOLA et al. 2007). In comparison to the values responsible for causing subchronic toxic symptoms in cattle through forage, which is 0.5 Cd mg kg $^{-1}$ d.m. (GARCIA, MILAN 1998), the concentrations of this metal in our study were lower.

Table 1

Content of lead and cadmium in plant samples (mg kg^{-1})

Distance from the road (m)	Plant species	Lead		Cadmium	
		mean	coefficient of variation (%)	mean	coefficient of variation (%)
1	*Dactylis glomerata*	2.66	24.7	0.234	45.1
	Arrhenatherum elatius	2.52	27.8	0.19	34.2
	Alopecurus pratensis	3.30	32.8	0.18	32.9
Mean for 1 m		2.72	14.7	0.40	45.9
5	*Dactylis glomerata*	4.72	23.1	0.45	25.8
	Arrhenatherum elatius	5.00	47.2	0,19	32.1
	Alopecurus pratensis	3,70	22.9	0,14	38.3
Mean for 5 m		3.15	44.3	0.13	103.6
10	*Dactylis glomerata*	3.42	32.9	0.28	37.9
	Arrhenatherum elatius	3.96	36.9	0.33	33.2
	Alopecurus pratensis	3.46	45.3	0.11	23.1
Mean for 10 m		2.93	36.5	0.17	64.5
15	*Dactylis glomerata*	2.20	23.9	0.15	21.9
	Arrhenatherum elatius	1.64	17.8	0.08	23.9
	Alopecurus pratensis	5.18	67.1	0.13	34.1
Mean for 15 m		2.45	66.5	0.16	53.9
Mean for all distances		2.84	44.4	0.22	78.5

Moreover, the levels of Cd observed in plants were lower than the EU limits and the background value given by RENGEL (2004).

Table 2

Grasses with the lowest and highest bioaccumulation of the investigated elements

Distance from the road (m)	Maximum		Minimum	
	Pb	Cd	Pb	Cd
1	*Alopecurus pratensis*	*Dactylis glomerata*	*Arrhenatherum elatius*	*Alopecurus pratensis*
5	*Arrhenatherum elatius*	*Dactylis glomerata*	*Alopecurus pratensis*	*Alopecurus pratensis*
10	*Arrhenatherum elatius*	*Arrhenatherum elatius*	*Dactylis glomerata*	*Alopecurus pratensis*
15	*Alopecurus pratensis*	*Dactylis glomerata*	*Arrhenatherum elatius*	*Arrhenatherum elatius*

The multiple linear regression analysis (Figures 1, 2) showed that the variability of the lead content depended on the distance from the road and can be described by the following equation: $y = -0.565x^2 + 2.78x + 0.743$; for cadmium the euquation was $y = -0.0\ 44x^2 + 0.193x + 0.051$.

The stages of the function described by the above equations show that the greatest accumulation of these elements in plants occurred in a distance of 5-10 m from the road. The ruminants which wander and graze along roadsides feed on these grasses, while birds and domestic fowls feed there on insects and earthworms (Awofolu 2005, Basgel, Erdemogl 2006). The transport of metals through the food chain and their accumulation are likely to cause health problems, especially in animals in higher links in the food chain. Thus, accumulation and toxicity of this metal for ruminants grazing on plants along these roads is very important.

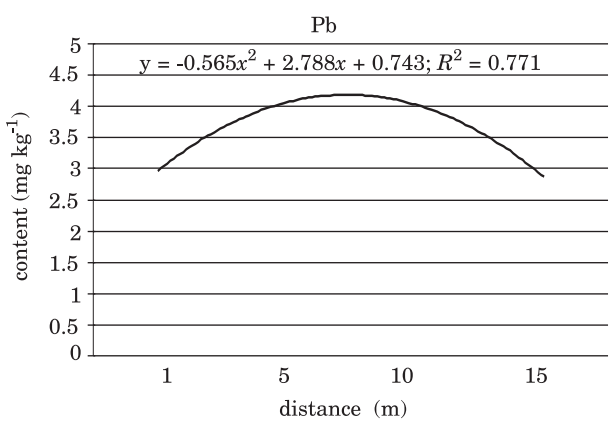

Fig. 1. Multiple regression equations describing the influence of the distance from the road on the content of lead in the analysed plants

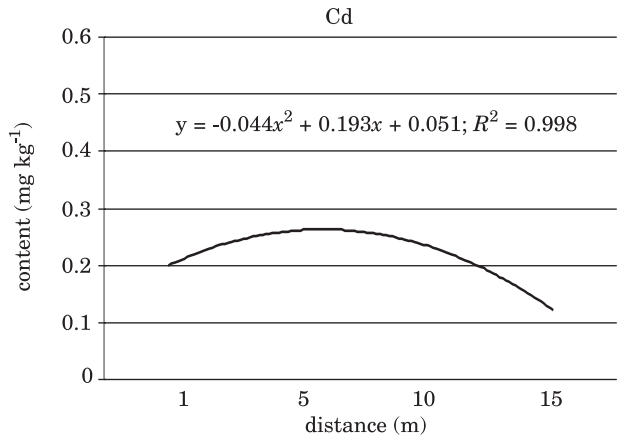

Fig. 2. Multiple regression equations describing the influence of the distance from the road on the content of cadmium in the analysed plants

As reported by SWAILEH et al (2004), the average metal concentrations in scabwort leaves was clearly below the range of metal concentrations in plant leaves considered phytotoxic. However, the concentrations of Pb, Cd, and Zn in roadside samples of scabwort leaves were higher than reported in leaves of the same plant from a control site (SWAILEH et al. 2001).

CONCLUSIONS

1. Lead and cadmium accumulation in grass growing along a road depended on the type of grass and the distance from the road.

2. Regardless of the grass species, the highest level of heavy metals was found in the plant material collected at a 5-metre distance from the road, and the average lead content was nearly 17-fold higher than that of cadmium.

3. Irrespective of the distance from the road, lead was largely accumulated by tall oat grass and meadow foxtail, while cadmium was absorbed mainly by orchard grass.

4. The grass species recommended for sowing on lead contaminated land is orchard grass while meadow foxtail is a better choice on the cadmium polluted soil.

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