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PASSIVE BIOMONITORING OF INFLUENCE OF THE COMMUNICATION TRAFFIC ON DEPOSITION THE POLLUTION NEAR THE MOTORWAY

PASYWNY BIOMONITORING WPŁYWU RUCHU KOMUNIKACYJNEGO NA DEPOZYCJĘ ZANIECZYSZCZEŃ W POBLIŻU AUTOSTRADY

Abstract: The article presents the results of studies carried out within passive biomonitoring, including the assessment of deposition of heavy metals (Ni, Cu, Zn, Cd, Hg and Pb), which can be found in the local atmospheric aerosol due to communication traffic in A4 motorway near Proszkow (Opole Province). *Pleurozium schreberi* moss samples collected 120 m away from the motorway along the distance of 3000 m, were used in the study. Wind directions frequency in the area were taken into consideration when selecting the measurement points. Heavy metals were determined with the use of flame atomic absorption spectrometry (F-AAS). The study results indicate that communication traffic in A4 motorway influences high content of the selected analytes in its vicinity; the pollution is carried in wind direction along certain distance.

Keywords: passive biomonitoring, mosses, heavy metals

Introduction

Biological methods of assessment of environment condition assume the use of various organisms (plants and animals) in monitoring air, water and soil quality [1–5]. Some examples include the use of mosses or lichens [6, 7], where mosses are perceived as one of the main biomonitors of atmospheric aerosol pollution [8,9]. Thanks to their specific structure and accumulation of nutrients with all their surface, they are able to accumulate also any pollution from atmospheric aerosol in their bodies. The most popular species used in air quality biomonitoring are: *Pleurozium schreberi*, *Hypnum cupressiforme* and *Hylocomium splendens*. The studies of mosses in biomonitoring allow to assess the degree of pollution of the studied areas and to identify the sources

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and dispersion directions of pollution. Passive biomonitoring enables qualitative and quantitative comparison of locations, taking into consideration the level of pollution with analytes, in order to, for example, identify pollution sources [10]. It also enables assessment of the current deposition of pollution in the local scale, taking into consideration point, area or linear emission sources [11]. Passive biomonitoring allows to asses also seasonal changes of analytes concentrations [10].

The results of studies of heavy metals accumulated in mosses are frequently interpreted with the use of *EF – Enrichment Factor*. The studies carried out in urbanised areas proved that the highest concentrations of the selected heavy metals, with the use of *EF* factor, are the result of the increased car traffic and industrial pollution emission [12]. Biomonitoring's undeniable benefit is simplicity of samples taking, economical advantage versus classical monitoring methods of air quality, however, its disadvantage is a limited study area, restricted to the zone in which a given biomonitor is present [13].

As a result of the studies carried out in Presov, eastern Slovakia, it was proved that heavy metals accumulation in lichens is related to the vehicle traffic intensity in the city. In that city, the streets located in the heavy traffic zone were more polluted with such metals as Cr, Ni, Pb or Zn, in comparison to the areas with less intense traffic [14]. A comparison of heavy metals concentrations accumulated in mosses collected in countryside and urbanised areas confirmed that the moss samples taken from urbanised areas contained twice as much of Ni, Cd, Pb and Cr and almost six times more zinc. Such distribution of analytes in the mosses from urbanised areas is influenced by vehicles traffic and industry [15]. Other studies also confirm that heavy metal concentration is correlated with the intensity of communication traffic as the source of analytes deposition on mosses [16]. *Pleurozium schreberi* moss was used in other studies as a passive biomonitor along a national road. The samples were taken on windward and leeward sides (according to the wind rose and frequency). The samples were taken from various distances from the road, along 5 to 600 m. The results of the carried out research confirmed that moss accumulated larger quantities of analytes in the vicinity of the road (5 m) than the samples located in a distance (600 m). Other studies also confirm that metals concentrations in plants decrease with the increasing distance from a road or another emission source [17, 18]. Analytes concentrations were higher on the windward side [17]. The results of own research indicated that the largest depositions of metals occurs at a certain distance from the source of heavy metals emission, which are carried in line with the direction of the dominating wind [19].

The aim of the carried out research within passive biomonitoring, was to asses deposition of the selected analytes: Ni, Cu, Zn, Cd, Hg and Pb in mosses, as a result of communication traffic in A4 motorway, considering the wind rose.

Materials and methods

Material

Pleurozium schreberi mosses were used in the research. Mosses were collected in Niemodlinskie Forest, Proszkow Forest Region, Opolskie Province, Poland on October/

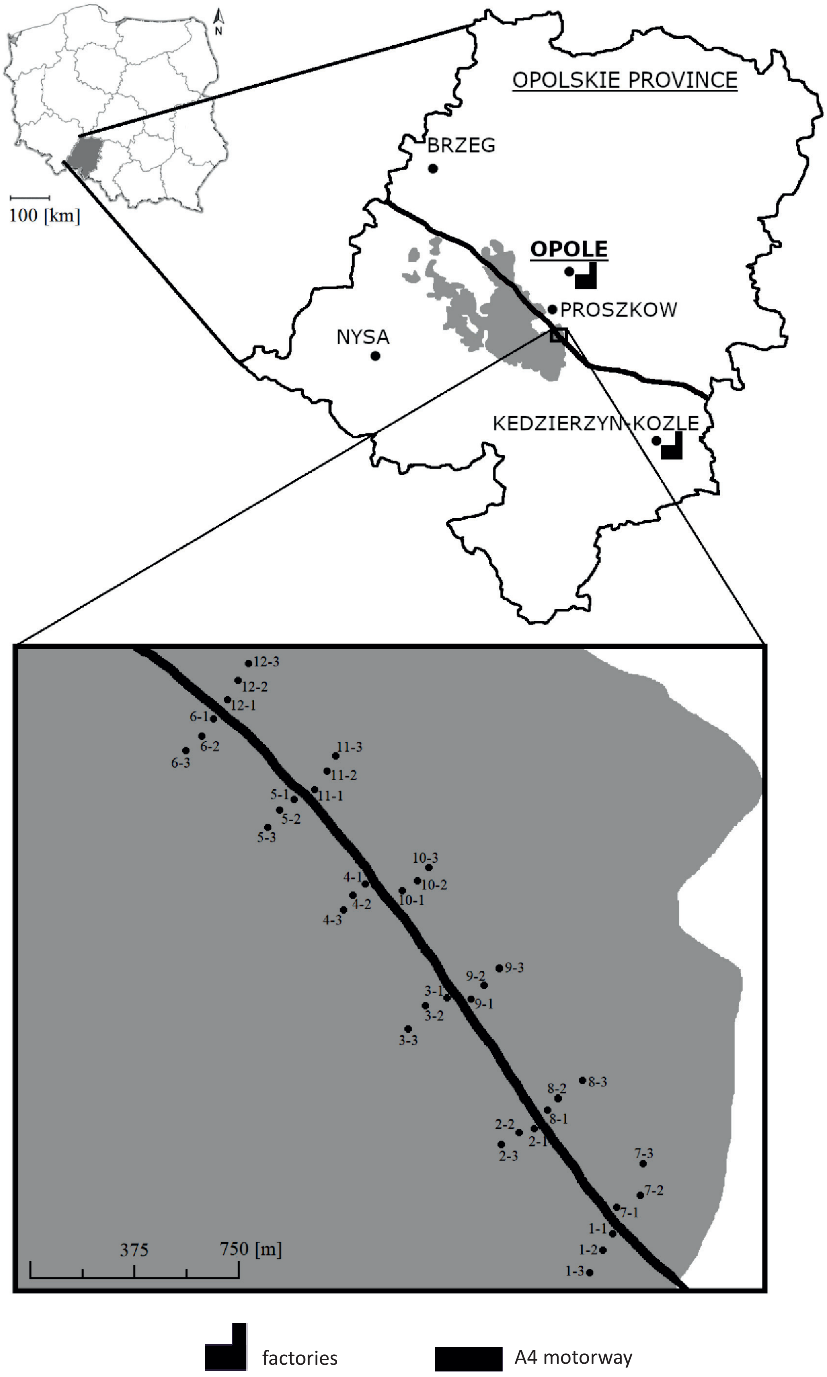

Fig. 1. Locations of measuring points

November 2019. Table 1 contains GPS locations of individual measurement points. Samples of mosses were collected along the distance of 3000 m. Distances between the points were 500 m, along A4 motorway. There were 18 measurement points on each, western and eastern side of the motorway, localised in its vicinity (1–1), 60 m away (1–2) and 120 m away from the road (1–3). (Fig. 1).

Table 1

GPS location of measurement points

Measurement point name	GPS location	Measurement point name	GPS location
1–1	50°32′9.33″N 17°54′16.48″E	7–1	50°32′12.14″N 17°54′16.59″E
1–2	50°32′7.54″N 17°54′13.96″E	7–2	50°32′13.37″N 17°54′21.38″E
1–3	50°32′4.89″N 17°54′10.91″E	7–3	50°32′16.78″N 17°54′22.21″E
2–1	50°32′22.11″N 17°54′3.03″E	8–1	50°32′24.09″N 17°54′5.43″E
2–2	50°32′21.82″N 17°53′59.88″E	8–2	50°32′25.44″N 17°54′7.52″E
2–3	50°32′20.50″N 17°53′56.32″E	8–3	50°32′27.29″N 17°54′12.55″E
3–1	50°32′36.53″N 17°53′50.63″E	9–1	50°32′37.96″N 17°53′52.59″E
3–2	50°32′37.58″N 17°53′43.69″E	9–2	50°32′39.38″N 17°53′54.93″E
3–3	50°32′35.08″N 17°53′40.30″E	9–3	50°32′41.17″N 17°53′58.42″E
4–1	50°32′53.07″N 17°53′34.36″E	10–1	50°32′51.94″N 17°53′40.92″E
4–2	50°32′51.77″N 17°53′31.57″E	10–2	50°32′52.81″N 17°53′43.58″E
4–3	50°32′50.26″N 17°53′29.75″E	10–3	50°32′54.29″N 17°53′45.82″E
5–1	50°33′4.06″N 17°53′20.61″E	11–1	50°33′5.34″N 17°53′25.05″E
5–2	50°33′2.98″N 17°53′17.77″E	11–2	50°33′7.46″N 17°53′27.63″E
5–3	50°33′1.26″N 17°53′15.72″E	11–3	50°33′9.28″N 17°53′29.12″E
6–1	50°33′15.74″N 17°53′6.45″E	12–1	50°33′17.92″N 17°53′8.70″E
6–2	50°33′13.60″N 17°53′3.49″E	12–2	50°33′19.73″N 17°53′10.60″E
6–3	50°33′11.91″N 17°53′0.40″E	12–3	50°33′21.74″N 17°53′12.60″E

Method

Each moss sample, with a mass of 1.000 ± 0.001 g d.m., (d.m. – dry mass) was prepared in this way and mineralised in a mixture of nitric acid (V) and hydrogen peroxide (HNO_3 65 % : H_2O_2 37 % = 5:3) using a Speedwave Four Berghof, DE microwave oven. The mineralisation process was carried out at a temperature of 180 °C.

Heavy metals (Ni, Cu, Zn, Cd and Pb) were determined using an atomic absorption flame spectrometer (F-AAS) type iCE 3500 (series 3000) made by Thermo Scientific, USA. Mercury was determined in plant samples (mass of each sample 0.040 ± 0.001 g d.m.) using the mercury analyser AMA 254 made by Altec Ltd (CZ).

Quality control

In Table 2, the instrumental detection limits (*IDL*) and instrumental quantification limits (*IQL*) for the spectrometer iCE 3500 are presented. The results were converted into 1 kg of sample. Calibration of the spectrometer was performed with a standard solution from ANALYTIKA Ltd. (CZ). The values of the highest concentrations of the models used for calibration (5 mg/dm^3 for Ni, Cu, Zn, Pb; 2 mg/dm^3 for Cd) were approved as linear limits to signal dependence on concentration. Concentrations of metals were determined in solution after mineralisation and dilution and were filtered into volumetric flasks of 20 cm^3.

Table 2

The instrumental detection limits (*IDL*)
and instrumental quantification limits (*IQL*) for the spectrometer
iCE 3500 [mg/dm^3] [20]

Metal	*IDL*	*IQL*
Ni	0.0043	0.050
Cu	0.0045	0.033
Zn	0.0033	0.010
Cd	0.0028	0.013
Pb	0.0130	0.070

In Table 3, concentrations of heavy metals in certified reference materials BCR-482 *lichen*, produced at the Institute for Reference Materials and Measurements, Belgium, are shown.

Table 3

Comparison of measured and certified concentrations in BCR-482 *lichen*

Metal	BCR-482 *lichen*		AAS		
	Concentration	Uncertainty	Average	±*SD**	*Dev.***
	[mg/kg d.m.]				
Ni	2.47	0.07	2.16	0.32	–13.0
Cu	7.03	0.19	6.63	0.17	–5.70
Zn	101	2.20	95.1	2.30	–5.50
Cd	0.56	0.02	0.53	0.03	–5.30
Hg	0.00048	0.00002	0.000450	0.000016	–9.80
Pb	40.9	1.40	38.2	1.00	–6.60

* Standard deviation.

** Relative difference between the measured (c_z) and certified (c_c) concentration $100\% \cdot (c_z - c_c)/c_c$.

n.d. – not determined.

Results and analysis

The research results were interpreted with the use of the wind rose. The data from the website [21], in which winds frequencies are prepared for Opole (the nearest town to the research area) was used (Fig. 2).

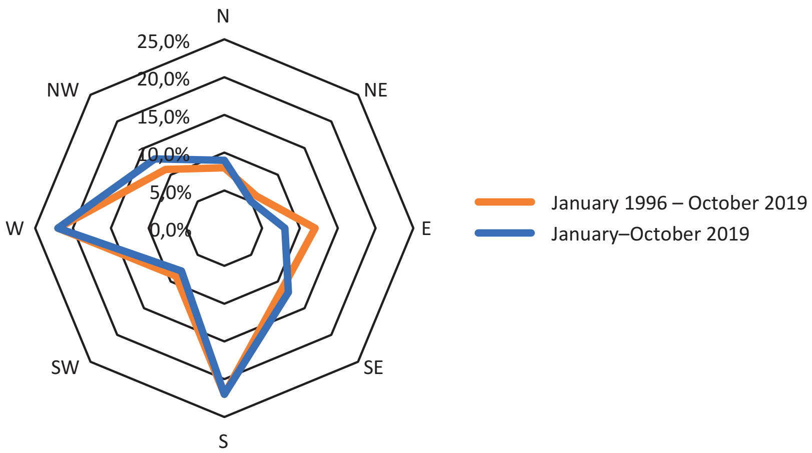

Fig. 2. Percentage analysis of the wind directions frequency for Opole

Anemological data for January–October 2019 indicate that western and southern winds dominate (22 % share) in the studied area. The data is also confirmed by a long-term analysis for the period January 1996 – October 2019. Therefore, the location of the moss samples collection points is in line with the dominating wind directions. The motorway is a landscape feature which divides the study area into the left (western) and right (eastern) side. Heavy metal pollution levels are different in both these parts. The following graph presents the sum of concentrations of individual heavy metals, determined in the moss samples collected on both sides of the motorway (Fig. 3).

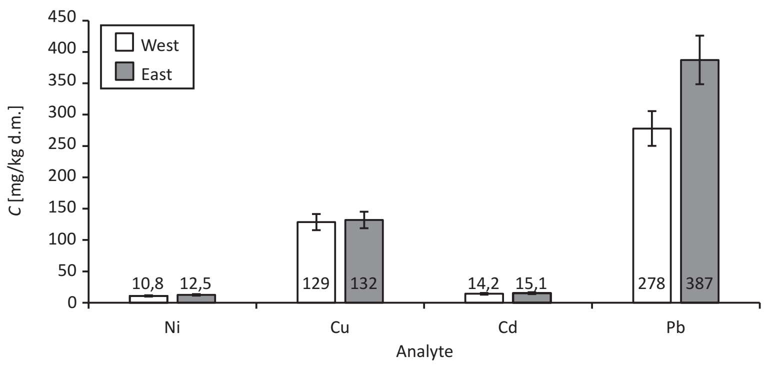

Fig. 3. Sum of concentrations of the selected metals on both sides of A4 motorway

The sum of mercury concentrations determined in mosses was higher by 0.06 mg/kg d.m. in the samples collected on the eastern side. Only the concentration of zinc was higher in the mosses collected on the western side of the motorway. For the presented results of the sum of concentrations of the metals presented in the graph it can be seen that metals concentrations determined in the mosses collected on the eastern side of the motorway are higher.

Figures 4–6 present the results of the studies for the selected pairs of measurement points, which confirm that analytes are carried together with dust particles along the wind direction.

The study results presented above indicate that heavy metals accumulate in mosses and their concentration depends on, among others, winds direction. It should also be

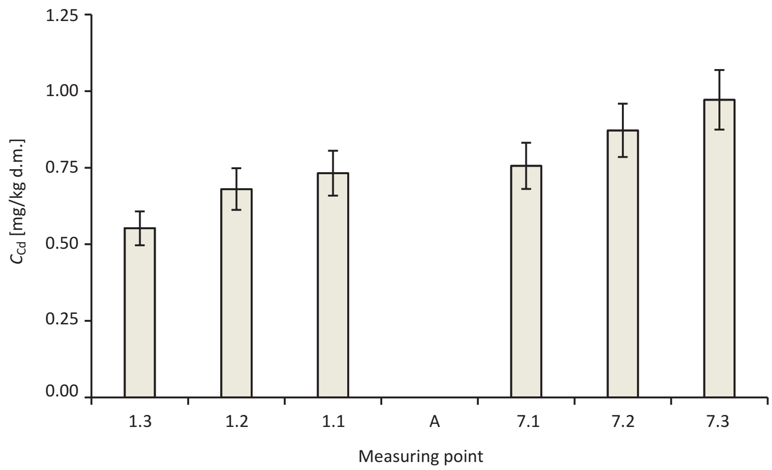

Fig. 4. Cd concentration determined in mosses collected from points 1 and 7 (A – A4 motorway)

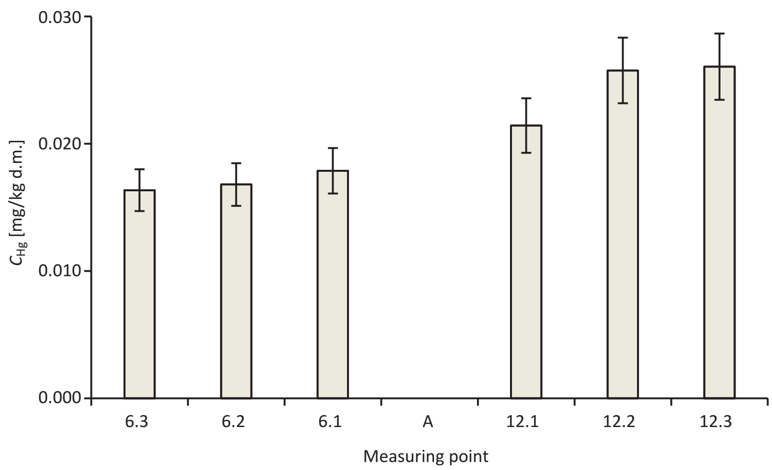

Fig. 5. Hg concentration determined in mosses collected from points 6 and 12 (A – A4 motorway)

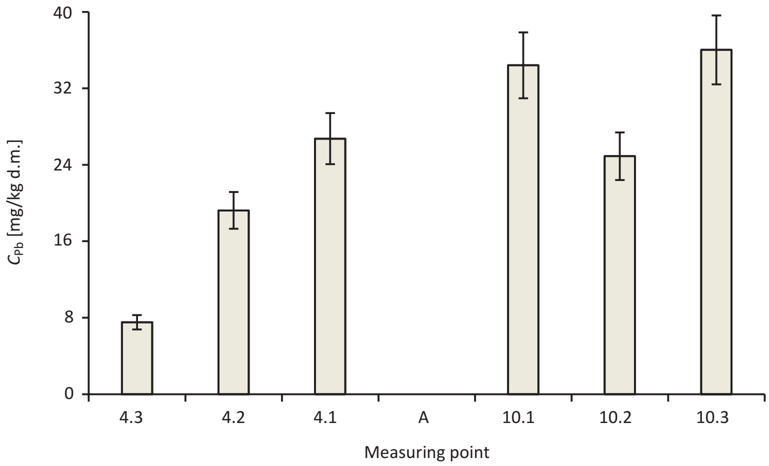

Fig. 6. Pb concentration determined in mosses collected from points 4 and 10 (A – A4 motorway)

stated, however, that the level of analytes concentration also depends on the distance from the emission source, i.e. the motorway. The highest concentrations of heavy metals were recorded mainly in the samples collected from the vicinity of the motorway (Fig. 7–10). Table 4 presented the results regarding the average concentrations of heavy metals determined in moss samples.

Wind is one of the key factors influencing distribution of dust particles in atmospheric aerosol and the content of heavy metals in moss samples [22]. This has been confirmed by previous studies within active biomonitoring. It was confirmed that pollution is carried not just along the wind direction but, additionally, it accumulates in the highest concentrations in the moss samples located at a certain distance, and not

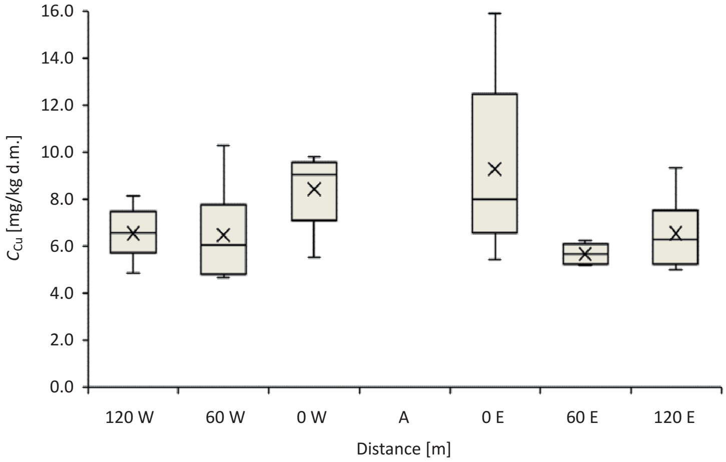

Fig. 7. Distribution of copper concentrations determined in the moss samples collected along the motorway (A); W – west, E – east

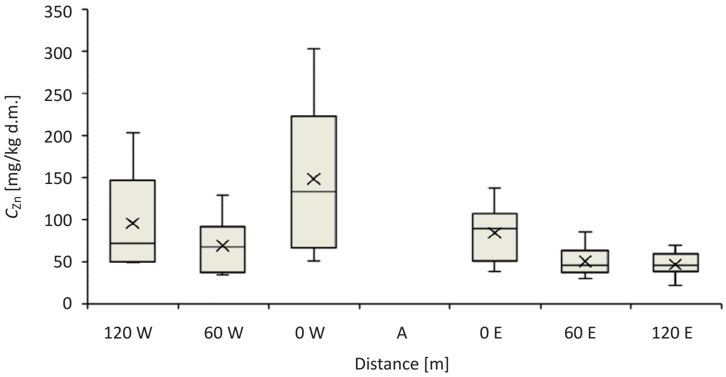

Fig. 8. Distribution of zinc concentrations determined in the moss samples collected along the motorway (A); W – west, E – east

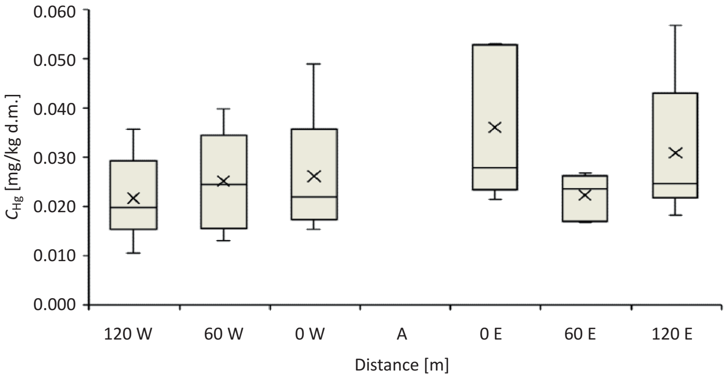

Fig. 9. Distribution of mercury concentrations determined in the moss samples collected along the motorway (A); W – west, E – east

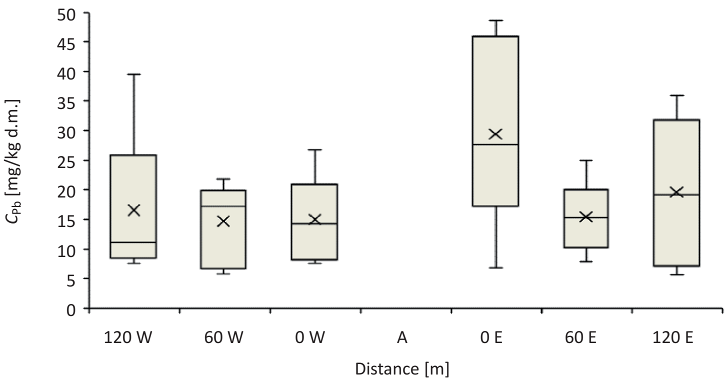

Fig. 10. Distribution of lead concentrations determined in the moss samples collected along the motorway (A); W – west, E – east

directly in the vicinity, of the emission source [19]. There results refer to Fig. 4–6, which present changing deposition of the selected analytes in mosses. The motorway was a factor separating samples and it was demonstrated that communication traffic will influence deposition of analytes in samples. That is why heavy metals concentrations in the samples from the eastern side, along the wind direction, are higher than concentrations of analytes in the mosses collected in the western side (Fig. 3, Table 4). Distribution of concentrations for the selected analytes in moss samples also depended on the frequency of certain wind directions occurring in the area (Fig. 2). However, it should be remembered that concentration of heavy metals in mosses is also influenced by the local pollution sources [23].

Table 4

Results of average heavy metal concentrations in moss samples [mg/kg d.m.]

Analyte	Distance from road [m]					
	West direction			East direction		
	120	60	0	0	60	120
Ni	1.86	1.31	1.67	1.52	2.10	1.46
Cu	6.55	6.46	8.42	9.26	5.66	6.53
Zn	95.6	69.1	148	84.3	50.2	46.9
Cd	0.826	0.808	0.738	0.899	0.829	0.792
Hg	0.022	0.025	0.026	0.036	0.022	0.031
Pb	16.6	14.7	15.0	29.4	15.5	19.7

The same moss species was used in similar studies carried out during a 5-year period. The authors confirm distribution of heavy metals in mosses in the vicinity of the motorway. The determined concentrations are similar or higher for such elements as nickel, zinc, cadmium or lead. The publication refers to the data on the wind direction, however, it was probably not taken into consideration. The studies confirmed, similarly to the experiment of the authors of this article, that the highest concentrations of heavy metals occur close to the motorway (2–4 m) and they decrease along with the increasing distance. In our opinion, however, this cannot be declared unambiguously, as the studies were carried out in the distance of only 14 m from the road. Undoubtedly, communication traffic influences high concentration of analytes in the vicinity of the motorway and accumulation if heavy metals in the mosses growing there [24]. This is the effect of the local emission of analytes to atmospheric aerosol, deposited by vehicles traffic (Fig. 7–10). This is also confirmed by active biomonitoring studies carried out in the vicinity of a racing track, where the authors found it possible to use moss in order to assess distribution of deposition of pollution emitted to atmospheric aerosol by car traffic [25].

The influence of an emission source is significant for the samples located in its vicinity. This has been confirmed by the results of heavy metals concentrations in bark or lichen samples, where concentration of the selected analytes was the highest in the vicinity of a copper mine. Despite the fact that lichens were not found in the vicinity of the mine, along with the increasing distance, the authors were able to find more and more samples, which may confirm the decreasing effect of the mine activity on the occurrence of lichens [26]. Other studies also confirmed the highest concentration of analytes in mosses in the mine vicinity, however they were not distributed further away [22].

Another example with the use of the *moss bag* method of biomonitoring indicates deposition of heavy metals in mosses and lichens along the ring road; however, such factors as climate conditions or wind direction should be taken into consideration. Taking into consideration the factor of wind direction is reflected in the study results, where it was demonstrated that there was a possibility of relative accumulation of analytes further away from the emission source – the ring road of Opole [27].

Summary and conclusion

Many researchers, who use mosses in passive biomonitoring, often analyse pollution level of a given area by pointing at local pollution sources, such as factories or intense communication traffic in urban areas, and also use mosses in assessment of analytes deposition in a selected study area [28–30].

The use of brophytes as biomonitors is a useful tool in monitoring the quality of environment, much better than vascular plants [9]. The use of mosses allows for obtaining a relatively quick and cheap information on the deposition of analytes and pollution of atmospheric aerosol. Collection of the material does not require special skills – it can be done even by a non-trained personnel; the appropriate and complex physical and chemical characteristics of mosses make them a simple but also multidimensional living tool, which allows for monitoring of large areas, regions or small scale pollution of a selected area [31].

However, it should be remembered that in this type of biomonitoring studies, the external and environmental factors, which can influence results, must be taken into consideration. Selection of a study conditions (e.g. time or location of an experiment) will be of key importance for the obtained results.

For the passive biomonitoring studies with the use of *Pleurozium schreberi* it was declared that communication traffic occurring in the selected section of A4 motorway influences deposition of heavy metals to atmospheric aerosol. The highest concentrations of analytes were determined in the mosses collected in the vicinity of the motorway. However, a detailed analysis of mosses collected from every measurement point indicates that transfer of pollution along the wind direction causes heavy metals accumulation in mosses in higher concentrations on the eastern side of the study area; analytes distribution in the highest concentrations for the selected points can be identified in the samples located even 120 meters away from the motorway. Previous studies with active biomonitoring confirm the prepared conclusions [19]. Obtaining similar results within passive monitoring of atmospheric aerosol may indicate a certain degree of correlation of the methods or, at least, similar results in the context of considering the same factors. Undoubtedly, selection of the study conditions will be relevant for drawing the proper conclusions on the condition of natural environment, in the context of air pollution with heavy metals.

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PASYWNY BIOMONITORING WPŁYWU RUCHU KOMUNIKACYJNEGO NA DEPOZYCJĘ ZANIECZYSZCZEŃ W POBLIŻU AUTOSTRADY

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Abstrakt: W pracy przedstawiono wyniki badań, przeprowadzonych w ramach biomonitoringu pasywnego, polegających na ocenie depozycji metali ciężkich (Ni, Cu, Zn, Cd, Hg i Pb), wzbogacających lokalnie aerozol atmosferyczny w skutek ruchu komunikacyjnego na autostradzie A4 w pobliżu miejscowości Prószków (województwo opolskie). Do badań wykorzystano próbki mchów *Pleurozium schreberi,* które pobrano w pobliżu autostrady na dystansie 3000 m i w odległości od niej do 120 metrów. Przy wyborze punktów pomiarowych uwzględniono częstotliwość kierunku wiatru na tym terenie. Metale ciężkie oznaczono metodą absorpcyjnej spektometrii atomowej ze wzbudzaniem w płomieniu (F-AAS). Wyniki badań wskazują na to, iż ruch komunikacyjny na autostradzie A4 wpływa na wysoką zawartość wybranych analitów w najbliższym jej otoczeniu, przy czym zanieczyszczenia są przenoszone zgodnie z kierunkiem wiatru również na dalsze odległości.

Słowa kluczowe: pasywny biomonitoring, mchy, metale ciężkie