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SOIL AND PLANT CONTAMINATION WITH HEAVY METALS IN THE AREA OF THE OLD RAILWAY JUNCTION TARNOWSKIE GÓRY AND NEAR TWO MAIN RAILWAY ROUTES

SKAŻENIE GLEBY I ROŚLIN METALAMI CIĘŻKIMI NA TERENIE STAREJ CZĘŚCI WĘZŁA KOLEJOWEGO TARNOWSKIE GÓRY I DWÓCH STRATEGICZNYCH SZLAKÓW KOLEJOWYCH

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The content of heavy metals in the soil and dandelion in the area of the old part of the railway junction Tarnowskie Góry and the surroundings of two main railway routes was investigated. The highest contamination with heavy metals has been found at reloading ramp. The level of contamination clearly decreased accordingly to the distance gradient from the track.

INTRODUCTION

Heavy metals are amongst most frequently found and intensively studied of the many chemical substances that contaminate the environment. This is demonstrated by the increasing number of publications concerning this topic. The natural content of heavy metals in soil results from the type and pH of the soil, its age, the climate and the topography of the site [1], while increased content of these metals in the soil is caused by anthropogenic pollution on both local and large scale [2, 3].

Due to its sorption properties, soil acts as a filter that retains various substances (including heavy metals) which have been put in it as a result of human activities. Industrial and vehicular emissions are the main sources of pollution. Therefore, particularly high concentrations of heavy metals in soil occur nearby large industrial plants and along motor transport routes [3, 4, 5].

Railway areas are thought to be sites of intensive heavy metal and organic compound emissions [6], although there are only few articles dealing with this problem [7, 8]. The aim of this study was to investigate the content of heavy metals in the soil and in a chosen plant (*Taraxacum officinale* Wiggers) which is used for bioindication purposes, in the area of the old part of the railway junction Tarnowskie Góry and the surroundings of two of main Polish railway routes. Based on the obtained results an attempt was made to assess the influence of different activities (passenger and goods traffic, reloading, stoppage and rolling stock cleaning) carried out in the area of the railway junction on the contamination levels, as well as to assess the relation between the type of the railway track and heavy metal content in the gradient of distance from the track.

EXPERIMENTAL

Study area and material

The study area covered the railway junction Tarnowskie Góry and the surroundings of two railway routes: (a) Warsaw – Gdańsk near the town Iłowo, (b) Katowice – Gdynia near the towns Warlubie and Laskowice. The railway junction Tarnowskie Góry was established around 1863. Between 1985 and 1990 large part of it underwent modernisation. The modernisation involved, amongst others, exchanging wooden for concrete sleepers, removing the top layer of soil and exchanging the breakstone. Currently the Tarnowskie Góry railway junction is one of the largest railway junction in Europe. Samples were collected in the following parts of the junction: the rolling stock cleaning bay, platforms, railway siding and the reloading ramp. The elements of the junction from which the samples were collected had not been modernised and thus constitute its old part. Such selection of the study site allows for a comparison with the previously studied contamination in the area of the railway junction Iława Główna [8]. The control sample was collected at the distance of 2 kilometres from the junction's border. The (a) railway route is a high traffic route where passenger transport dominates (electric traction). The (b) railway route (electric traction) is also a high traffic route, but goods transport prevails there. The average daily traffic is 43 passenger trains and 10 goods trains for the (a) route and 44 passenger trains and 69 goods trains for the (b) route. This information was obtained at the Informatics Centre of the PKP (Polish State Railways). Study sites on the (a) route were selected near the town Iłowo (Ciechanów province), and on the (b) route – in Bory Tucholskie (Tucholskie Coniferous Forests), near the town Warlubie (Bydgoszcz province), in an area which is free of large industrial plants. Such selection of the study area fulfilled the assumed conditions (area which is not used agriculturally and which is situated far from human settlement) and allowed for the collection of soil and plant samples with relatively low anthropopressure. Along both of the routes the samples were collected at the gradient of distances from the railway track. Soil from the 0 – 20 cm layer provided the material for analysis. Samples were collected with hand – held, twisting sampler (*Egner's* stick). Each time 15 – 20 individual samples were collected which constituted mean mixed samples. Plant samples were collected in the same study points.

Soil

One gram of ground and sifted through a sieve with 2 mm holes soil was mineralised in a hot mixture of concentrated acids: sulfuric(VI), nitric(V) and chloric(VII) – (1: 5: 20). The resulting extract was vaporized and the remains were dissolved in HCl.

Plants

Five grams of dried and ground green parts of *Taraxacum officinale* were mineralised in accordance with the instruction given above.

The flame atomic absorption technique was used to established lead, copper, cadmium and zinc contents in the soil and plant material. Cobalt, chromium and molybdenum contents were established with the ICP technique. Mercury levels were established by the total mercury establishing flameless technique using an AMA 254.

RESULTS AND DISCUSSION

Heavy metal content in the soil of different parts of the railway junction Tarnowskie Góry is presented in Table I.

The level of heavy metals contamination of the soil in the area of the whole railway junction Tarnowskie Góry clearly exceeds the control level. However, it is less varied

Table I. Heavy metal content in the soil in the railway junction Tarnowskie Góry (ppm)

Metal	Cleaning bay	Platforms	Siding	Reloading ramp	Control
Lead	202	312	180	244	128
Cadmium	3,2	3,8	4,2	5,2	2,3
Chromium	16	29	27	33	2
Mercury	0,171	0,213	0,015	0,242	0,086
Molybdenum	1	2	5	3	<1
Zinc	484	794	684	784	210
Cobalt	7	7	6	8	<1
Copper	115	202	85	304	6

among different parts of the junction than in the area of the railway junction Iława Górna, where the areas of the railway siding and the rolling stock cleaning bay were far more polluted than the areas of the reloading ramp and platforms [8].

Lead content in the soil of the railway junction Tarnowskie Góry is the lowest on the railway siding where it exceeds the control level only 1.4 fold. It is the highest in the platform area, where its level is 312 ppm, which exceeds the control level 2.35 times. The fact that the control level is exceeded by a relatively small amount may be explained by the control's high level of contamination (much higher than in Iława) due to industrial emissions of lead, cadmium and zinc in the area of the railway.

Cadmium contamination is at its highest level in the area of the reloading ramp, but even there the control level (increased) is not exceeded more than two – fold. Contamination levels regarding this metal are lower in other areas of the junction and they are the lowest in the area of the rolling stock cleaning bay.

The chrome contamination is disturbingly high. Even in the cleaning bay area, where it is the lowest, the control level is exceeded eight times. In other parts of the junction the contamination is more or less even and it exceeds the control level more than ten – fold. Molybdenum content in the soil from the cleaning bay area is only slightly higher than the control level, which is lower than the detection limit. The highest molybdenum content (5 ppm) is found in the railway siding area. In Iława the railway siding was also the most polluted area of the junction, but the molybdenum level is only 3 ppm there. Zinc contamination in the cleaning bay area exceeds the control level 2.3 – fold and it is much lower than in other parts of the junction. Zinc level in the railway siding area is 684 ppm, which exceeds the control level 3.2 times. Near the platforms and the reloading ramp, zinc contamination is even higher, exceeding the control level more than 3.7 times. In Iława, zinc contamination of the reloading ramp and the platform areas was much smaller. The soil from the siding area shows similar levels of zinc contamination and the cleaning bay soil (the most polluted) is more than 2.5 times more contaminated than the cleaning bay soil in Tarnowskie Góry.

Cobalt contamination is at the level of 6 – 8 ppm. The control level is very low, below the detection threshold. Copper is the undisputed record holder in terms of contamination levels amongst all the analysed heavy metals. Even the least polluted siding soil is contaminated 14 times more than that from the control area regarded for the purpose of calculation as below 1 ppm. The cleaning bay soil contains 19 times more copper, platform area soil – almost 34 times and the most polluted reloading ramp soil contains more than 50 times more copper than the control sample. Copper contamination in Iława is also high, but its distribution among various parts of the junction is different. The rolling stock cleaning bay and the railway siding are several times more polluted there than the platforms and the reloading ramp.

Table II presents heavy metal contents in *Taraxacum officinale* in the Tarnowskie Góry junction.

Table II. Heavy metal content in *Taraxacum officinale* plants (ppm) in the area of the railway junction Tarnowskie Góry

Metal	Cleaning bay	Platforms	Siding	Reloading ramp	Control
Lead	67,1	14,6	89	78	5,9
Cadmium	3,9	4,1	2,8	4,6	1,2
Chromium	25	57	30	24	23
Mercury	0,59	0,049	0,051	0,045	0,0034
Molybdenum	2	3	2	2	1
Zinc	269	179	370	292	90
Cobalt	1,7	2,1	2,4	1,2	1
Copper	151	38	35	66	12

Plants from the whole railway junction area, apart from those collected in the platform area are strongly polluted and their levels of contamination are higher than those in Iława (7). Siding area plants are the most strongly polluted and the lead content exceeds the control level 15 – fold there. Cadmium contamination of plants is not very high. It is the highest in the reloading ramp area where it exceeds the control level almost four times. Chromium contamination in plants from the areas of the reloading ramp and the cleaning bay is similar to that from the control site. The control level is slightly exceeded in the railway siding area. The highest concentration of chrome is found in plants that grow next to the platforms, but even there it is not very high (57 ppm) and exceeds the control level only twice.

High differences are found in the contamination of plants with mercury. While in the areas of the platforms, reloading ramp and the railway siding the mercury contamination is more or less even and it exceeds the control level 15 times, in the area of the cleaning bay the mercury level reaches 0.59 ppm which exceeds the control level more than 170 times (!). Exactly the same pattern of mercury contamination distribution was found in Iława and the mercury level in *Taraxacum officinale* plants was higher still there. The high content of mercury in the plants from the cleaning bay area is caused by washing the rolling stock that carries materials which constitute sources of mercury emissions, such as coal, cement, non – ferrous metal ores and chemical compounds that contain mercury. This should be remembered that the cleaning bay in Iława is far less modern than that in Tarnowskie Góry.

Molybdenum contamination of plants from the cleaning bay, railway siding and reloading ramp areas is even and it exceeds the control level twice. Only near the platforms it is slightly higher and the control level is exceeded 3 – fold. Zinc contamination of plants in Tarnowskie Góry is similar to that from Iława. It is the lowest near the platforms where the control level is exceeded less than twice, near the cleaning bay and the reloading ramp it is exceeded 3 times and in the side track area – 4 times. Cobalt contamination is the lowest on the reloading ramp and the highest on the siding. However, even there it is only 2.4 higher than the control level. Copper levels in plants clearly exceed the control level. It is the highest in samples from the cleaning bay area (12 times the control level). However, the level of copper content in plants is still much lower than that found in the soil.

Heavy metal content in the soil near the railway route Warsaw – Gdańsk in Iłowo is presented in Table III.

Table III. Heavy metal content in the soil near the railway route Warsaw – Gdańsk (Iłowo) in a gradient of distances from the track (ppm)

Metal	0 m	15 m	30 m	50 m	100 m	Control
Lead	52	52	29	20	14	21
Cadmium	1,6	1,6	0,9	<0,5	<0,5	<0,5
Chromium	33	33	15	9	6	4
Mercury	0,094	0,094	0,191	0,076	0,043	0,055
Molybdenum	<1	<1	<1	<1	<1	<1
Zinc	159	50	42	32	26	18
Cobalt	6	3	3	2	2	<1
Copper	85	20	21	10	4	3

Soil contamination with all the analysed heavy metals near the high traffic (mostly passenger) route decreases with the increasing distance from the railway track. The fact that control levels are strongly exceeded, particularly at small distances from the track, supports the hypothesis that railway transport is a source of heavy metal emissions. However, the decrease in the heavy metal content in the soil shows different patterns for different metals. Chromium, zinc and copper content exceeds control levels more than 10 times, decreases rapidly at the distance of 15 m and then the decrease is slower. The decrease in cadmium, lead and cobalt content is more gradual. Mercury content increases from the track to the distance of 30 m and then decreases. Molybdenum content is below the detection threshold even on the track.

Heavy metal content in plants from the same study transect is presented in Table IV.

Metal contents in *Taraxacum officinale* samples does not show such regular decrease as that in soil. Copper, cobalt, zinc, molybdenum and chromium levels are the highest right next to the track, but it is more or less even at all the distances investigated. Lead content varies with the distance gradient and does not exceed the control level by far. Cadmium level within the distance of 30 m is below the detection threshold and it is only slightly higher at the distances of 50 and 100 m. Mercury level (similarly

Table IV. Heavy metal content in *Taraxacum officinale* plants near the railway route Warsaw – Gdańsk (Iłowo) in a gradient of distances from the track (ppm)

Metal	0 m	15 m	30 m	50 m	100 m	Control
Lead	12,1	23	12,2	24	18	14
Cadmium	<0,5	<0,5	<0,5	0,9	0,6	<0,5
Chromium	35	17	22	18	22	34
Mercury	0,021	0,016	0,057	0,038	0,034	0,013
Molybdenum	2	1	<1	<1	2	1
Zinc	49	74	71	65	57	56
Cobalt	1,4	<0,5	0,7	0,8	<0,5	0,9
Copper	35	15	20	20	18	15

to that in soil) is the highest at the distance of 30 m from the track, where the control value is exceeded 4 times and it is lower at smaller and larger distances from the track.

Heavy metal content in the soil near the railway route Katowice – Gdynia is presented in Table 5.

Table V. Heavy metal content in the soil near the railway route Katowice – Gdynia in a gradient of distances from the track (ppm)

Metal	0 m	15 m	30 m	50 m	100 m	Control
Lead	40 43	10 11	7 <5	13 6	–* 15	6
Cadmium	3,0 4,5	<0,5 <0,5	<0,5 <0,5	<0,5 <0,5	–* <0,5	<0,5
Chromium	31 40	6 3	2 2	2 2	–* 2	2
Mercury	0,139 0,157	0,021 0,131	0,005 0,015	0,026 0,031	–* 0,019	0,017
Molybdenum	<1 1	<1 <1	<1 <1	<1 <1	–* <1	<1
Zinc	269 382	33 31	16 18	11 34	–* 26	10
Cobalt	5 5	2 <1	<1 <1	<1 <1	–* <1	<1
Copper	195 122	8 5	3 2	2 2	–* 2	5

* no data available for the town of Warlubie due to the topography of the area. For each metal the first value refers to the Warlubie transect and the second value – the Laskowice transect

The content of all the studied metals clearly decreases in the distance gradient. It is worth noticing that the decrease in copper level is far more rapid here than near the route (a). Copper content next to the track is very high. No molybdenum contamination was found.

Heavy metal content in *Taraxacum officinale* plants next to the railway route Katowice – Gdynia is presented in Table 6.

Table VI. Heavy metal content in *Taraxacum officinale* plants near the railway route Katowice – Gdynia (Warlubie) in a gradient of distances from the track (ppm)

Metal	0 m	15 m	30 m	50 m	100 m	Control
Lead	13	5,1	4,0	4,6	–*	5,4
Cadmium	0,5	<0,5	<0,5	<0,5	–*	0,7
Chromium	22	32	47	19	–*	66
Mercury	0,053	0,015	0,015	0,015	–*	0,014
Molybdenum	<1	1	<1	1	–*	<1
Zinc	71	49	50	72	–*	79
Cobalt	1,1	0,5	<0,5	<0,5	–*	0,6
Copper	58	14	14	18	–*	17

* No *Taraxacum officinale* due to the topography of the area

Copper, cobalt, zinc and mercury content decreases in the distance gradient. No molybdenum or cadmium contamination has been found. Chromium content increases to the distance of 30 m and then decreases, throughout the transect remaining at a level below the increased control values.

Such pattern of contamination allows for a conclusion that intense passenger traffic is a source of emission of mainly copper, cobalt, zinc and chromium which come from traction materials (grease, impregnants, traction cables and brake blocks). However, it does not constitute a danger of molybdenum contamination.

Intense goods traffic causes high iron pollution next to the track due to the heavy weight of the trains which causes more rapid abrasion of wheels and tracks. The higher total number of trains on route (a) causes intense abrasion of traction cables which results in a high copper contamination next to the track.

CONCLUSIONS

The main conclusions of this study can be summarised as follows:

1. The performed studies confirm the high emission level of heavy metals into the environment by the railway transport.

2. The relationship between soil and plant contamination has been founded.

3. The decrease in the level of contamination and the distance from the routes has been proved.

4. The level of contamination in the railway junction is much higher than along respective routes.

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SOIL AND PLANT CONTAMINATION WITH HEAVY METALS IN THE AREA OF THE OLD RAILWAY JUNCTION TARNOWSKIE GÓRY AND NEAR TWO MAIN RAILWAY ROUTES

Summary

Heavy metals (Pb, Cd, Cr, Hg, Mo, Zn, Co, Cu) content was determined in soil and plant samples collected in the different areas of the railway junction Tarnowskie Góry, as well as, near two main railway routes, i. e. Warsaw – Gdańsk and Katowice – Gdynia. In Tarnowskie Góry soil and plant samples were collected in four functional parts of the junction, i. e. the rolling stock cleaning bay, platform area, railway siding and loading ramp.

It was found that the contamination of soil and plants by heavy metal was the highest in loading ramp. A particularly high pollution level of copper was observed. The contamination level near the railway routes decreased accordingly to the distance from routes which suggests pollutant role of railway transport.

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SKAŻENIE GLEBY I ROŚLIN METALAMI CIĘŻKIMI NA TERENIE STAREJ CZĘŚCI WĘZŁA KOLEJOWEGO TARNOWSKIE GÓRY I DWÓCH STRATEGICZNYCH SZLAKÓW KOLEJOWYCH

Streszczenie

Określono zawartość metali ciężkich (Pb, Cd, Cr, Hg, Mo, Zn, Co, Cu) w próbkach gleby i roślin zebranych w różnych częściach węzła kolejowego Tarnowskie Góry oraz przy strategicznych liniach kolejowych, tj Warszawa – Gdańsk i Katowice – Gdynia. W Tarnowskich Górach próbki gleby i roślin zostały zebrane w czterech funkcjonalnych częściach węzła, tj. myjni, peronach, bocznicy i placu przeładunkowym.

Wykazano, że najwyższe zanieczyszczenie metalami ciężkimi występuje na placu przeładunkowym. Szczególnie wysoki poziom zaobserwowano dla miedzi. Poziom zanieczyszczenia metalami ciężkimi przy liniach kolejowych spadał wraz ze wzrostem odległości od toru, co sugeruje, że transport kolejowy jest stałym tych zanieczyszczeń.

REFERENCES

1. *Alloway B.J.*: Heavy metals in soils, John Wiley & Sons, New York (1990).
2. *Esser K.B.*: Reference concentrations for heavy metals in mineral soils, oat, and orchard grass (*Dactylis glomerata*) from three agricultural regions in Norway. Water, Air and Soil Pollution 1996, 89, 375–397.
3. *Chukwuma Ch.*: Comparison of the accumulation of cadmium, lead and Zinc in Cultivated and Wild Plant species in the derelict Enyigba lead-zinc mine, Toxicological and Enviromental Chemistry 1993, 38, 167–173.
4. *Legret M., Colandini V., Demare D., Balades J.D., Madiec H.*: Pollution par les metaux lourds liee a l'infiltration des eaux de ruissellement urbaines dans une chaussee poreuse a structure reservoir, Enviromental Technology 1994, 15, 1183–1191.
5. *Niederer M., Maschka-Selig A., Hohl Ch.*: Monitoring polycyclic aromatic hydrocarbons (PAHs) and heavy metals in urban soil, compost and vegetation. Environ. Sci and Pollut. Res. 1995, 2 , 83–89.
6. II Conference of UIC Coordinators for Environmental Protection: (1996) Paris, Conference Abstracts, p. 10.

7. *Malawska M, Wiłkomirski B.*: Analiza skażeń gleby polichlorowanymi bifenylami (PCBs) i metalami ciężkimi (Cd, Pb) w otoczeniu szlaków kolejowych oraz węzła Iława Główna, Rocz. PZH 1997, 48, 343–350.
8. *Malawska M. Wiłkomirski B.*: An analysis of soil and plant (*Taraxacum officinale*) contamination with heavy metals and polycyclic aromatic hydrocarbons (PAHs) in the area of railway junction Iława Główna, Water, Air and Soil Pollution 2000 – accepted for publication.

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