Rocznik Świętokrzyski. Ser. B – Nauki Przyr. 34: 171–180, 2013

Polska Akademia Nauk – Oddział w Krakowie,
Kieleckie Towarzystwo Naukowe

The selected trace elements in soil of railway stations in north-eastern Poland

Wybrane pierwiastki śladowe w glebie dworców kolejowych w północno-wschodniej Polsce

BOGUSŁAW WIŁKOMIRSKI , MAŁGORZATA SUSKA-MALAWSKA, BARBARA SUDNIK-WÓJCIKOWSKA, TOMASZ STASZEWSKI

Streszczenie. Zanieczyszczenie środowiska metalami ciężkimi wynikające z transportu drogowego było przedmiotem wielu badań, podczas gdy liczba prac dotycząca tego zjawiska w odniesieniu do transportu kolejowego jest znacznie skromniejsza. Ponadto w ostatnio opublikowanych pracach zajmowano się tylko "klasycznymi" metalami ciężkimi (Pb, Cd, Cu, Zn, Hg, Fe, Co, Cr, Mo). Informacje dotyczące zanieczyszczenia gleby terenów kolejowych innymi metalami są sporadyczne.

Celem obecnych pracy jest dostarczenie informacji dotyczącej poziomu zanieczyszczenia gleby terenów kolejowych rzadko oznaczanymi pierwiastkami, takimi jak: mangan, tytan, arsen, cyna, bar, nikiel i glin. Ze względu na brak prac o podobnym charakterze, takie badania powinny być prowadzone, gdyż wymienione pierwiastki wywierają niekorzystne efekty zdrowotne.

Obecne badania zostały przeprowadzone na terenie czterech stacji kolejowych zlokalizowanych w północno-wschodniej Polsce, tj.: w Białymstoku, Sokółce, Hajnówce i Kuźnicy Białostockiej. Cały teren badanych stacji charakteryzował się podwyższonym w stosunku do kontroli poziomem badanych pierwiastków, szczególnie niklu i cyny. Wśród przebadanych stacji najwyższe poziomy oznaczanych pierwiastków stwierdzono w Białymstoku, który jest największym węzłem kolejowym regionu, z intensywnym ruchem pasażerskim i towarowym.

Słowa kluczowe: stacje kolejowe, zanieczyszczenie, pierwiastki śladowe, gleba.

***Bogusław Wiłkomirski**, Department of Environmental Protection and Modeling, The Jan Kochanowski University in Kielce, Świętokrzyska 15, 25-406 Kielce, Poland, bowi@ujk.edu.pl*

***Małgorzata Suska-Malawska, Barbara Sudnik-Wójcikowska**, Institute of Botany, University of Warsaw, 02-096 Warsaw, Poland*

***Tomasz Staszewski**, Institute of Ecology of Industrial Areas, Kossutha 6, 40-833, Katowice Poland*

INTRODUCTION

Modern transportation includes many possibilities of movement of people and goods, but it is evident that exist two main types of land transportation, i.e. road and rail. Since the first railway was opened in Great Britain this type of transportation has started to develop rapidly. Each type of anthropopressure, including transportation, causes many disturbances and contamination in the environment.

Environmental pollution with heavy metals resulting from the transportation sector has been analyzed mainly in relation to the effect of the road traffic, because it was generally thought that rail transportation was less harmful to the environment than road traffic. However, the operation of railway tracks involves the presence of solid contaminants on the line. The organic contaminants may originate from the dispersion of freight goods or from the lubricate oils and condenser fluids, as well as from the application of herbicides and substances used for impregnation of wooden structures (mostly ties) (Malawska, Wiłkomirski, 1999; Malawska, Wiłkomirski, 2001; Brooks, 2004; Wiłkomirski et al., 2011).

Heavy metals are amongst the most frequently found and intensively studied chemical substances that contaminate the environment. This is due their detrimental effects to the environment and human health (Turkdogan et al., 2003, Gheorgiu et al., 2007, Kawata et al., 2007). Heavy metal emission in the vicinity of railway tracks derives from trains and rail infrastructure, i.e. from fuel combustion, construction materials abrasion and cargo leakage. Literature searching showed that the concentration of the investigated metals in soil covering station area was generally higher that found in centers of cities proving that the railway transportation was an important linear source of soil contamination. In the most recently published papers contamination of soil and plants with heavy metals dealt with the "classical" heavy metals (Pb, Cd, Cu, Zn, Hg, Fe, Co, Cr and Mo) (Malawska, Wiłkomirski, 2001; Chilrud et al., 2005, Bukowiecki et al., 2007, Liu et al., 2009, Wiłkomirski et al., 2011).

The aim of the present study is to present information concerning pollution level of soil with rarely determined elements (Ba, As, Mn, Ni, Sn, Ti) in the area of various functional parts of the four biggest railway stations in Podlaskie voivodeship. Due to scarcity of information on emission of these elements by the railway system, some

data on soil contamination can help to illustrate the level of railway impact on the environment.

EXPERIMENTAL

Study area

The present investigations were carried out in the area of different functional parts of four railway stations located in north-eastern Poland, in Podlaskie voivodeship i.e. Białystok, Sokółka, Hajnówka and Kuźnica. Tracks (referred to as "running trucks") are located in the passenger part of the stations and focuses main stream of local and long distance trains.

The railway siding consists of many tracks where goods trains wait for unloading. The sampling area was situated in the most frequently used tracks of the railway siding.

The rolling stock cleaning (referred to as "cleaning bay or old cleaning bay") are the separated and unsecured railway tracks with no facilities preventing the leakage.

Classification yard, receiving yard and hold yard are the parts of the junction in which trains are put together and prepared for travel.

The region of north-eastern Poland covered mostly by forests is relatively clean, since no heavy industry is concentrated there. The junctions having such location are the relevant places to investigate the influence of railway transportation on environmental pollution.

Soil sampling

Soil samples were collected in predetermined investigation areas in May 2012. The railway basement soil collected from the depth of 0–20 cm was sieved (5 mm sieve) directly at the sampling area. At each location 15–20 individual subsamples were taken thereby providing a mean mixed sample of about 1 kg of the soil representing ballast bed od examined place. Dried soil samples were sieved (1 mm sieve) in the laboratory and used for further analysis.

Heavy metal analysis

Trace element analyses were carried out after mineralization using aqua regia in open system.

Heavy metal contents (Ba, As, Mn, Ni, Sn, Ti) were established by ICP-OES technique using iCAP6500, Thermo DUO Scientific equipment.

The quality assurance and quality control was performed by analyzing the standard samples of known composition. All the analyses were carried out in Central Chemical Laboratory of Polish Geological Institute which possesses accreditation certificate AB 283.

RESULTS AND DISCUSSION

The levels of the investigated trace element (As, Ba, Mn, Ni, Sn, Ti) determined in collected soil samples are presented in Table 1.

The content of these elements is rarely determined during routine investigation dealing with "classical" heavy metals i.e. Pb, Cd, Cu, Zn, Hg, Fe, Co, Cr and Mo. In majority of cases the contents of heavy metals in the soil of the stations was higher than at control sites, with exception of aluminum. Excluding the Białystok station area, concentration of this metal in other investigated station was not significantly higher inside the station when compared to their outside.

The arsenic concentration in soil was the lowest among all elements determined in the present study. Although the ratio of this content (investigation area to control) cannot be mathematically calculated (the level in control area was below the detection limit) it is obvious that the arsenic concentration is strongly increased. The arsenic concentration in soil of Białystok station varied from 7 to 23 mg/kg. The level of arsenic in soil of investigated stations is increased comparing to control but it is still relatively low when compare with a study of former railway corridors in Australia which revealed considerable surface (0-10 cm) contamination with As (<20 to >1000 mg/kg) (Smith et al., 2006). However, the arsenic level determined by us is significant in relation to the study of urban areas. In soil survey made in Berlin when about 4000 soil samples were taken in suburban areas with little or no contamination as well as industrial areas in and around the city, mean concentration of arsenic was 5.1 mg kg-1 for the entire town area with 6,8 mg kg-1 in its industrial part (Birke, Rauch, 2000).

Table 1. Concentration of investigated elements in soil collected from the main railway station in the north-eastern Poland
Tabela 1. Stężenie badanych pierwiastków w glebie zebranej z głównych stacji kolejowych w północno-wschodniej Polsce

Sampling site *Miejsce pobierania próbek*	As mg/kg	Ba mg/kg	Mn mg/kg	Ni mg/kg	Sn mg/kg	Ti mg/kg
Białystok – running track	11	111	718	38	10	364
Białystok – cleaning bay	10	147	471	24	10	205
Białystok – old cleaning bay	23	360	2348	138	21	804
Białystok – classification yard	7	80	384	27	20	186
Białystok – receiving yard	22	307	1463	75	13	335
Białystok – control	***	60	341	5	***	145
Hajnówka – running truck No 5	5	148	339	18	9	276
Hajnówka – hold yard	5	71	272	10	11	165
Hajnówka – control	***	62	349	5	***	85
Sokółka – running track No 10	8	75	363	15	14	264
Sokółka - running track No 3	10	217	548	29	22	257
Sokółka – running track No 5	10	224	573	29	23	254
Sokółka – hold truck	5	57	358	13	6	168
Sokółka – running track No 11	4	90	451	10	9	204
Sokółka – control	***	67	293	6	3	180
Kuźnica – railway siding	5	137	266	14	3	177
Kuźnica – railway siding	9	172	353	24	3	233
Kuźnica – control	***	51	381	4	***	169

*** below detection limit.

The highest concentrations of barium (360 and 307 mg/kg), which exceeded the control level 6-fold and 5-fold respectively, were determined in the soil of Białystok old cleaning bay and receiving yard. Representative background soil concentrations of barium calculated for Cuyahoga County is 98.9 mg/kg (Christman et al., 2013).

Manganese concentration in soil exceeded the control level in Białystok up to 7 times, reaching the highest value – 2348 mg/kg at the old cleaning bay. In the soil of the other investigated stations the concentration of manganese is relatively low, being approximately around the level of control. Investigation of the railway effect of on soil contamination was performed in the mountain region of Sichuan, China (Liu et al., 2009). Samples of soil were collected inform a flat, cut slope and embankment. Mean concentrations of manganese at all three sites were significantly elevated compared to those at the control site. The highest concentration of manganese (676 mg/kg) occurred at the cut slope site, which was about four times that of the local background level. Our investigation proved that elevation of manganese level can be more significant. The content of manganese in Białystok old cleaning bay and receiving yard is significantly higher than detected close to high-traffic roads in the centre of Rome, where the concentration of this metal in soil was found to be 546 mg/kg (Malizia et al., 2012).

The whole area of the investigated stations contains elevated concentration of nickel. The highest concentration of this metal was observed Białystok, reaching in old cleaning bay and receiving yard the level 138 and 75 mg/kg, respectively. The level of nickel in old cleaning bay exceeded the control level approximately 28-fold. According to the Institute of Soil Science and Plant Cultivation (IUNG), normal concentration of Ni in soil ranges from 2 to 50 mg/kg and a permissible threshold value is 50 mg/kg (Szczepocka, 2005). The inner city and surrounding area of Berlin showed enriched concentrations of nickel (mean value of 10,7 mg kg-1 with maximal value of 71.2 mg kg-1), with respect to the regional geochemical background (5.3 mg kg-1) for more than 2000 samples (Birke, Rauch, 2000).

The soil in whole area of the investigated stations contains elevated concentrations of tin exceeding the control level several times with the highest concentration of 23 mg/kg in the platform area in Sokółka running truck.

Relevant literature data indicated the concentration of tin in soil in the range of 0,6 to 8.6 mg/kg (Eriksson, 2001). The average values of tin in 15 different types of soils in the USA ranged between 0.6 and 1.7 mg/kg (Eckel, Jacob, 1988). In 32 soil samples collected along the highway and motor way connecting Nigda with Adana in Turkey the tin concentration ranged from 6.8 to 15 mg kg-1 with the mean concentration of 8.56 mg/kg (Yalcin et al. 2007). Comparing the literature results with these yielded in our investigation one can say that the tin level, although not very high is relatively significant.

Titanium content in soil is at increased level in Białystok station and in the other stations has oscillated around the similar level as in the control site. The highest content of these metal was determined in Białystok old cleaning bay and reached 804 mg.kg, exceeding the control level more than 5 times. Mean concentrations of titanium at all other investigated station were not significantly elevated compared to those at the control site.

In the Table 2 the mean values of investigated elements in soil in Poland and Europe are presented. The increase of investigated trace elements in soil outside railway areas are caused mostly by pesticides (As, Sn), protecting paints (As, Sn), road transportation (Mn, As, Ni), combustion (all examined elements), metal ores (all examined elements).

Table 2. Mean values of selected trace element in soil of Poland and Europe according to soil contamination atlases

Tabela 2. Średnie zawartości wybranych pierwiastków śladowych w Polsce i Europie, zgodnie z atlasami zanieczyszczeń

	As	Ba	Mn	Ni	Sn	Ti
Poland*	<5 mg/kg, Geogenic anomalies in places of bog ores. In Białystok-Dojlidy up 46 mg/kg (probably anthropogenic anomaly)	63 mg/kg	—	7 mg/kg	—	—
Europe**	5 mg/kg	65 mg/kg	382 mg/kg	14 mg/kg	3 mg/kg	—
Northern Europe***	<3 mg/kg	< 50 mg/kg	< 600 mg/kg MnO	<11 mg/kg	<3 mg/kg	<300 mg/kg TIO_2
Poland****	<5 mg/kg	48 mg/kg	267 mg/kg	6 mg/kg	—	34 mg/kg

* (Pasieczna 2003)

** (De Vos et al. 2006)

*** (Salminen et. al 2005)

**** (Lis J., Pasieczna. 1995) – Atlas geochemiczny Polski w skali 1:2 500 000. Wyd. Geologiczne. Warszawa.

CONCLUSIONS

The content level of investigated elements was generally higher in the area of all the functional parts of main stations in Podlaskie voivodeship than in the control sites. The highest contamination of soil with rarely determined elements was found in Białystok, where movement of trains is very intensive, which confirms an advanced process of the analyzed metals emission from the wheel and track abrasion. The highest contamination of soil in old cleaning bay proved that procedure of open air washing of rolling stock on separated and unsecured railway track with no facilities preventing the leakage is the serious source of contamination. The concentration of some investigated elements in soil within the studied area was higher than the corresponding values found along traffic roads and in city centers. This confirms that railway transportation is an important linear source of soil contamination.

Acknowledgements We wish to acknowledge our indebtedness to the Ministry of Science and Higher Education for grant no. N N 305 05 24 40 which made this work possible. We are also very grateful to Polish Rail Regional Head Office in Białystok for permission to investigate the working railway stations.

REFERENCES

Birke M., Rauch U., 2000. Urban geochemistry: Investigations in the Berlin metropolitan area. Geochemistry and Health, 22: 233–248.

Brooks K. M., 2004. Polycyclic aromatic hydrocarbon migration from creosote-treated railway ties into ballast and adjacent wetlands. Research Paper FLP-RP-617. Madison W1: US Department of Agriculture, Forest Service, Forest Products Laboratory.

Bukowiecki, N., Gehrig, R., Hill, M., Lienemann, B., Zwicky, C. N., Buchmann, B., 2007. Iron, manganese and copper emitted by cargo and passenger trains in Zurich (Switzerland): Size-segregated mass concentrations in ambient air. Atmospheric Environment, 41, 878–889.

Chillrud S. N., Grass D., Ross J. M., Coulibaly D., Slavkovich V., Epstein D., et al., 2005. Steel dust in the New York City subway system as a source of manganese, chromium and iron exposures for transit workers. Journal of Urban Health, 82, 33–42.

Christman T., Martin J., Myers F., Rasic C., Sainet E., Steigerwald-Dick V., 2013. Evaluation of Background Metal Soil Concentrations in Cuyahoga County – Cleveland Area Summary Report for Ohio EPA's Voluntary Action Program

De Vos W., Tarvainen T. , Salminen R., Reeder S., De Vivo B., Demetriades A., Pirc S., Batistamarsina K., Ottesen R., O'Connor P., Bidovec M., Lima A., Sievers U., Smith B., Taylor H., Shaw R., Salpeteou I., Gregorauskiene V., Hamalic J., Slaninka I., Lax K., Gravesen P., Birke M., Breward N., Ander E., Jordan G., Duris M., Klein P., Locutra J., Bellan A., Pasieczna A., Lis J., Mazreku A., Gilucis A., Heitzmann P., Klaver G., Petersell V., 2006. Geochemical Atlas of Europe. Part 2. Interpretation of Geochemical Maps, Additional Tables Figures, Maps, and related Publications. Geological Survey of Finland. Espoo.

Eckel W.P., Jacob T.A., 1988. Ambient levels of 24 dissolved metals in U.S. surface and ground waters. National Meeting, American Chemical Society, Division of Environmental Chemistry 28:371–372.

Eriksson J.E., 2001. Concentrations of 61 trace elements in sewage sludge, farmyard manure, mineral fertilizers, precipitation and in oil and crops. Swedish EPA Rep 5159, Stockholm.

Gheorgiu C., Cable J., Margoliese D.J., Scott M.E., 2007. Effects of waterborne zinc on reproduction, survival and morphogenesis of Gyrodactylus turnbulli (Monogenea) on guppies (Poecilla reticulata). International Journal of Parasitology. 37: 275-381.

Kawata K., Yokoo H., Shimazaki R., Okabe S., 2007. Classification of heavy metal toxicity by human DNA microarray analysis. Environmental Science and Technology. 41: 3769-3774.

Lis J., Pasieczna., 1995. Atlas geochemiczny Polski w skali 1:2 500 000. Wyd. Geologiczne. Warszawa

Liu H., Chen L.P., Ai Y.W., Yang X., Yu Y.H., & Zuo Y.B., 2009. Heavy metal contamination in soil alongside mountain railway in Sichuan, China. Environmental Monitoring and Assessment, 152, 25-33.

Malawska M., Wiłkomirski B., 1999. An analysis of polychlorinated biphenyls (PCBs) content in soil and plant leaves (Taraxacum officinale) in the area of the railway junction Iława Główna. Toxicological and Environmental Chemistry. 70: 509-515.

Malawska M., Wiłkomirski B., 2001. An analysis of soil and plant (T*araxacum officinale*) contamination with heavy metals and polyaromatic hydrocarbons (PAHs) in the area of the railway junction Iława Główna (Poland). Water, Air and Soil Pollution. 127: 339-349.

Malizia D., Giuliano A., Ortaggi G., Masotti A., 2012. Common plants as alternative analytical tools to monitor heavy metals in soil. Chemistry Central Journal, 6 (Suppl. 2): S6. doi: 10.1186/1752-153X-6-S2-S6.

Pasieczna A., 2003. Atlas zanieczyszczeń gleb miejskich w Polsce.. PIG. Warszawa.

Salminen R., Batista M., Bidovec M., Demetriades A., De Vivo B., De Vos W., Duris M., Gilucis A., Gregorauskiene V., Halamic J., Heitzmann P., Lima A., Jordan G., Klaver G., Klein P., Lis J., Locutura J., Marsina K., Mazreku A., O'Connor P., Olsson S., Ottesen

R., Petersell V., Plant J., Reeder S., Salpeteur L., Sandsyrom H., Sievers U., Steenfelt A., Tarvainen T., 2005. Geochemical Atlas of Europe. Part 1. Background information, methodology and maps. Geological Survey of Finland. Espoo.

Smith E., Smith J., Naidu R., 2006. Distribution and nature of arsenic along former railway corridors of South Australia. Science of the Total Environment. 15; 363(1-3): 175-82.

Szczepocka A., 2005. Kryteria oceny zanieczyszczeń gleb metalami ciężkimi. Zeszyty Naukowe SGSP, 32, 13-27.

Turkdogan M. K., Kilicel F., Kara K., 2003. Heavy metals in soils, vegetables and fruits in the endemic upper gastrointestinal cancer region in Turkey. Environmental Toxicology and Pharmacology. 13: 175-179.

Wiłkomirski B., Sudnik Wójcikowska B., Galera H., Wierzbicka M., Malawska M., 2011. Railway transportation as a serious source of organic and inorganic pollution). Water, Air and Soil Pollution. 218: 333-345.

Yalcin M. G., Battaloglu R., Ilhan S., Tümüklü A. and Topuz D., 2007. Heavy metal contamination along the Nigde-Adana highway, Turkey. Asian Journal of Chemistry, 19 (2), 1506-1518.