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Mercury contamination of railway areas in South-East Poland

Zanieczyszczenie terenów kolejowych rtęcią w południowo-wschodniej Polsce

MAREK JÓŹWIAK, MAŁGORZATA ANNA JÓŹWIAK

Streszczenie. Funkcjonowanie transportu kolejowego w sposób niekorzystny wpływa na stan środowiska naturalnego. Wśród wielu zanieczyszczeń pojawiających się na terenach kolejowych istotne znaczenie ma rtęć. Przeprowadzone w ramach projektu badawczego NCN badania terenów kolejowych południowo-wschodniej Polski wykazały, że zanieczyszczenie rtęcią uzależnione jest od intensywności ruchu pociągów oraz od odległości od torowiska.

Słowa kluczowe: zanieczyszczenie terenów kolejowych, rtęć, gleba.

Marek Jóźwiak, Małgorzata Anna Jóźwiak, *Uniwersytet Jana Kochanowskiego, Katedra Ochrony i Kształtowania Środowiska, ul. Świętokrzyska 15 bud. G, 25-406 Kielce, marjo@ujk.edu.pl*

INTRODUCTION

Railway transport is one of the main means of transport in the world, along with vehicle transport. It has functioned in Poland for 160 years and until 1990 is was the main means of transport. A characteristic feature of railway transport is that it takes up large areas of land. The length of railway line in Poland changed from 13 760 km in 1930 to 19 400 km in 2010. It was the greatest in 1990, when it amounted to 26 230 km. On average, there are 100 00 ha of land per 1 km of railway line. Railway transport has a significant effect on the condition of the environment. Threats to the environment caused by the railway are the result of the specificity of this branch of transport. It consists in railway rolling stock, i.e. rail traction vehicles and cars as well as rail infrastructure. The threats to the environment caused by the exploitation of railway infrastructure are connected with all components of the environment, i.e. lithosphere, atmosphere, hydrosphere and biosphere. However, it is commonly thought that railway transport has only slight impact on the environment. This stems from the fact that literature does not devote much attention to this problem. Finally, the studies of Tikka et al. (2001), Witting (2002), Lacey and Cole (2003), Moret et al. (2007), Liu et al. (2009), and in Poland Malawska and Wiłkomirski (1999, 2001), Wiłkomirski et al. (2011), Jóźwiak et al. (2012), Jóźwiakowa et al. (2012) brought the problem of high environmental pollution in railway areas into focus.

The specificity of the railway rolling stock and infrastructure leads to pollution that is typical for railway, especially the pollution of land, which may arise due to the following reasons: permeating of substances used in order to impregnate crossties; leakage of substances related to traffic; wear of the surface layer of traction feeder cables, rails, elements of rolling stock body and break shoe lining; transport of goods, especially metal ores, fuels, mineral oils, chemical substances; overload and storage of goods; and the use of herbicides. Among numerous kinds of contamination present in railway areas, mercury is the most significant one. The significance of mercury as a contaminative substance stems from the specificity of this metal, due to which it is more toxic than cadmium or lead, especially when it takes the form of methylmercury and elemental mercury. The objective of the study was to asses the level of mercury contamination of the railway areas in South-East Poland.

APPLIED STUDY METHOD

The studies were conducted as part of the project financed by the National Science Centre No. NN 305 061839 in 2010–2013, and their scope included railway areas in the South-East Poland (Fig. 1).

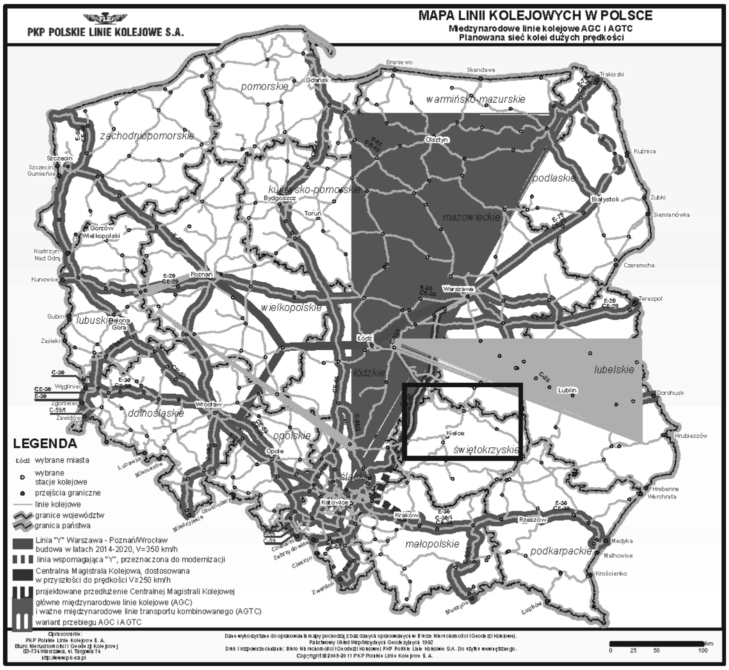

Fig. 1. Research area
Ryc. 1. Obszar badań

The testing areas were chosen on the basis of the data obtained in Regional Directorates of the company Polskie Linie Kolejowe. On the basis of the obtained information as to the intensity and kind of transportation, and during site inspections performed directly *in situ*, the areas for detailed *in situ* tests were chosen. The selected railway line sections included sections of the main and secondary railway lines as well as of lines with limited traffic. Each tested area was 550 m^2 and consisted of two stations limited by the width of sleepers and posts outside of the trackway, located 5 m and 10 m away (Fig. 2).

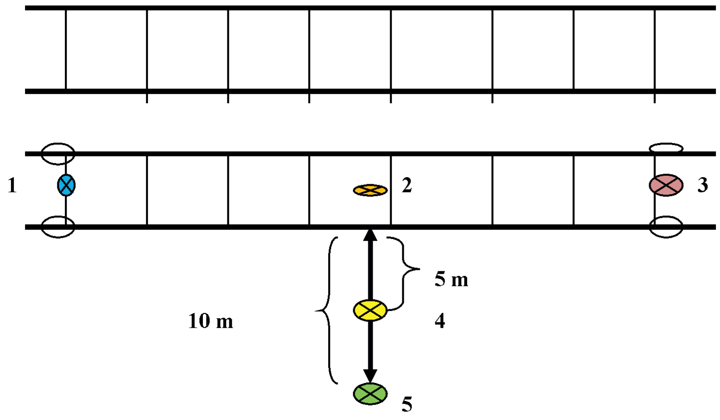

Fig. 2. Location of sampling points soil samples
Ryc. 2. Położenie punktów poboru próbek gleby

The samples of mineral material were collected in the selected points (Fig. 2) and underwent preliminary sieving *in situ* (Photo 1).

Photo 1. Sieving mineral material (Photo by M. Jóźwiak)
Fot. 1. Przesiewanie materiału mineralnego (fot. M. Jóźwiak)

The prepared material was documented, put into plastic bags and transported to Jan Kochanowski University in Kielce, the Department of Environmental Protection and Development, where it was dried in room temperature. Then, after separating the skeletal and earth fraction on sieves, the latter was marked for: granulometric composition using Casagranda's method as modified by Prószyński; pH using potentiometric method; and $CaCO_3$ using Tiurin's method. Mercury was determined in the Central Chemical Laboratory of the Polish Geological Institute (National Research Institute).

CHARACTERISTICS OF THE STUDIES AREA

The studies were carried out in the area of the railway junction Skarżysko-Kamienna and at the station Stąporków and the trackway in Barcza. Skarżysko-Kamienna is one of the largest railway junctions in the region. The history of the railway station in Skarżysko-Kamienna dates back to the end of the 19th century. Iwanogrodzko-Dąbrowska line was launched in 1885. In Kamienna village, which developed into the present Skarżysko-Kamienna, the line branched off to the East – to Ostrowiec and Bodzechów, and to the West – to Koluszki. The present railway junction Skarżysko-Kamienna is located at the crossing of the main railway routes from Warsaw to Cracow and from Łódź to Rzeszów. In the North-East part of the city there is a classification yard, which is the seat of the department of rail transport and the department of rail rolling stock of the company PKP Cargo (Photo 2).

Photo 2. Railway juction Skarżysko-Kamienna (Photo by M. Jóźwiak)
Fot. 2. Węzeł kolejowy Skarżysko-Kam (fot. M. Jóźwiak)

Stąporków is a railway station on the route from Skarżysko-Kamienna to Opoczno and Tomaszów Mazowiecki, where trains stopped. At present, only haul trains use this railway line, however rarely. Stąporków station is also a railway siding for haul trains (Photo 3).

Photo 3. Staporków railway station (Photo by M. Jóźwiak)
Fot. 3. Stacja kolejowa Stąporków (fot. M. Jóźwiak)

The research station Barcza is located near the main line Warsaw–Cracow. It is a single, 11-kilometers long track. It was built in the half of the 18th century. It starts at the railway station in Zagnańsk and ends near the mine Wiśniówka in a village of the same name. The track was used in order to transport aggregate from the mine to the main tracks in Zagnańsk. The track was closed in 1999. It had not been used at all for 13 years. Only in 2011 there have been taken actions aiming at the reconstruction of the old rail siding (Photo 4).

Photo 4. Barcza of railway siding (Photo by M. Jóźwiak)
Fot. 4. Bocznica kolejowa Barcza (fot. M. Jóźwiak)

RESULTS

The granulometric analysis of the samples collected between rails shows that they origin from light clay sand and light clay on surface I and silty clay on surface II. Silty clay is found between tracks, at the distance of 5 m and 10 m. The reaction of soils in the tested area of the station Skarżysko-Kamienna was chiefly neutral, almost alkaline or slightly alkaline. Slightly acid soils occurred rarely. This is caused by the presence of breakstone often used in railway subgrades. It contains large amounts of $CaCO_3$, which affects soil reaction. The conducted analysis of granulometric composition of ground samples shows that the main fraction is sand. Mechanical composition and granulometric group of samples are presented in Table 1.

Table 1. Selected features of Geastrum genus fungi are fund in the Świętokrzyskie Mts.
Tabela 1. Zawartość frakcji w próbkach podłoża na terenie kolejowym Polski południowo-wschodniej

Place of sampling *Miejsce poboru próbki*	Fraction *Frakcja*				Granulometric group / *Grupa granulometryczna*
	Sand *Piasek*	Coarse dust *Pył gruboziarnisty*	Fine dust *Pył drobnoziarnisty*	Loam *Ił*	
Between the railway tracks *Między szynami*	66	4	17	13	pgl
Between the railway tracks *Między szynami*	59	12	12	17	pgm
Between the railway tracks *Między szynami*	58	14	9	19	pgm
5 m from railway tracks *5 m od torowiska*	91	1	1	7	ps
10 m from railway tracks *10 m od torowiska*	86	3	4	7	ps

Soil reaction varied from pH 6.70 to pH 7.44 within rails, and from pH 6.92 to pH 5.38 at the distance of 5 m and 10 m (Fig. 3).

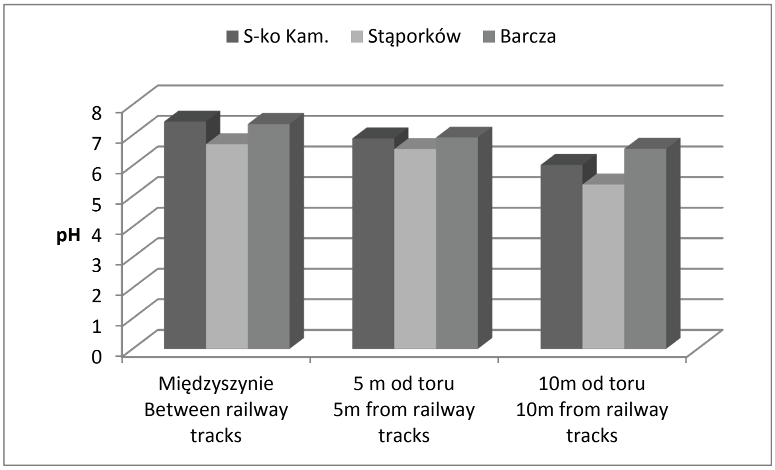

Fig. 3. pH grounds in the test points

Ryc. 3. pH podłoża w badanych punktach

In such edaphic conditions, mercury contamination in the ground varied from 0.018 mg Hg*mg^{-1}•s.m. to 0.256 mg Hg*mg^{-1}•s.m. The concentration of contamination depended on the intensity of train traffic and the distance from the railway subgrade. In the areas with intense train traffic, the concentration of mercury in the ground was the highest and it varied from 0.234 mg Hg*mg^{-1} •s.m. to 0.256 mg Hg*mg^{-1}•s.m. (Fig. 4). The lowest concentration of mercury was noted in the area of low train traffic: from 0.02 mgHg*mg^{-1} s.m. to 0.076 mgHg*mg^{-1}•s.m. (Fig. 5). Little concentration of Hg was noted also on the sidings: from 0.018 mgHg*mg^{-1}•s.m. to 0.098 mgHg*mg^{-1}•s.m. (Fig. 6).

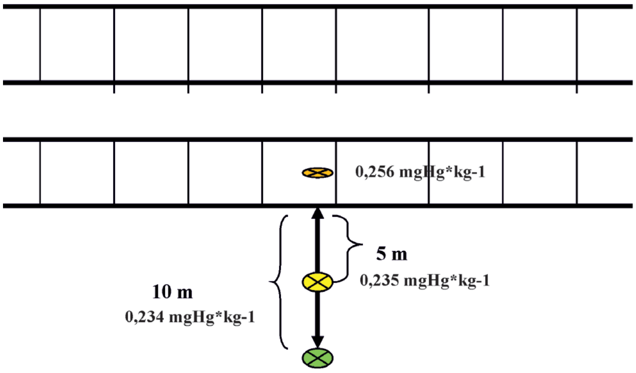

Fig. 4. Mercury contamination in the Barcza grounds

Ryc. 4. Zanieczyszczenie podłoża rtęcią w miejscowości Barcza

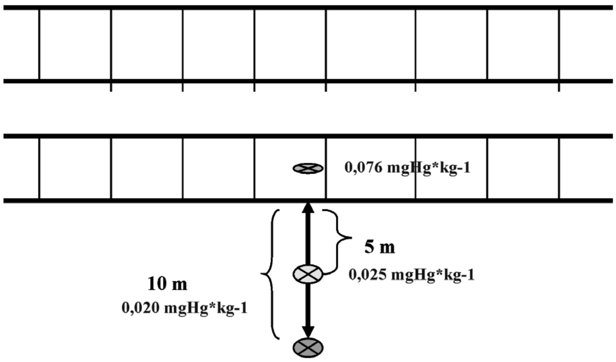

Fig. 5. Mercury contamination in the Stąporków grounds
Ryc. 5. Zanieczyszczenie podłoża rtęcią w miejscowości Stąporków

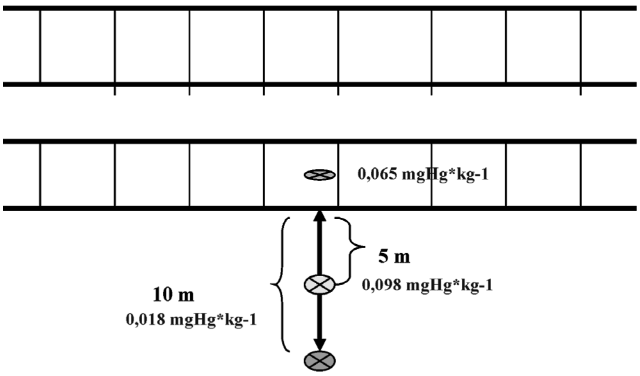

Fig. 6. Mercury contamination in the Skarżysko-Kamienna grounds
Ryc. 6. Zanieczyszczenie podłoża rtęcią w miejscowości Skarżysko-Kamienna

Mercury concentrations in the tested areas did not exceed the levels permitted by the Regulation of the Minister of the Environment of 2002 concerning mercury concentrations in soils located in industrial areas.

CONCLUSION

The study of the content of mercury in the environment caused by human activity is of utmost importance for human health and life. Due to its biological and chemical activity, mercury changes its form very quickly and travels throughout ecosystems and various elements of the environment, becoming a local, regional and often global problem. A very serious problem is that once introduced in the environment, mercury stays there forever (Langauer-Lewowicka, Palwas 2009; Pirrone, Wichmann-Fiebig 2003). The natural mercury content in soil depends on the kind of analysed soil. It is assumed that it is from 0.05 do 0.3 $mg*kg^{-1}$ (Kabata-Pendias, Pendias 1999). Mercury content in fresh mass of higher animals is from 0.005 to 5 ppb. According to UNEP Chemicals report (2002), mercury may be absorbed by an organism through respiratory system (84%), skin (1%) and food (5÷15%). Mercury accumulates in the tissues of higher animals and may go through the blood/brain barrier. About 90% of the absorbed mercury, both in the organic and inorganic form, accumulates in kidneys. Organomercury compounds show high lipophilicity; therefore, they easily go through the blood/brain barrier and accumulate in brain lipids. Organic mercury compounds are most dangerous for humans. It is related to the fact that the metal reaches brain cells quickly. The toxic effect is related to the connection with sulphhydryl, carboxyl and amine groups as well as amino acids, and it consists in blocking biochemical functions of these compounds (Walker et al. 2002)

Throughout the world, there are taken actions aiming at limiting the emission of mercury to the environment (European Commission 2003, 2004). The most important international documents and agreements related to this matter include Convention on Long-range Transboundary Air Pollution. One of its protocols covers the topic of heavy metals, including mercury. Namely, it is the Protocol on Heavy Metals, which takes into consideration the emission of cadmium, lead and mercury. Poland signed this document on 24 June 2004. It also signed Rotterdam Convention related to the international trade procedure of granting consent for using, among others, inorganic and organic mercury compounds as pesticides (the Convention became effective on 24 February 2004).

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REFERENCES

European Commission, 2003. Draft Reference Document on BAT for Large Combustion Plants Seville, Spain, March.

European Commission, 2004. Extended Impact Assessment Review, Institut pour un Développement Durable, Ottignies (Belgique).

Jóźwiak M., Jóźwiak M.A., Kozłowski R., 2012. The use of lichens as bio-indicators of pollution of railway land in SW Poland, International Conference ECOpole'12, Zakopane, 10–13 X 2012.

Jóźwiak M.A., Fałtynowicz W., Jóźwiak M., Kozłowski R., Wiłkomirski B., 2012. Lichens group in the area of railway juction Skarżysko-Kam. (Southern Poland), International Conference "Landscape and tourism in a sustainable development", Poland, Kielce, Sobków 5–7 June 2012.

Kabata-Pendias A., Pendias H., 1999. Biogeochemia pierwiastków śladowych, PWN, Warszawa.

Lacey R.F., Cole J.A., 2003. Estimating water pollution risks arising from road and railway accidents. Quarterly Journal of Engineering Geology and Hydrogeology. 36(2): 185–192.

Langauer-Lewowicka H., Palwas K., 2009. Niektóre aspekty środowiskowego narażenia na rtęć. Med. Środ. 12: 109–114.

Liu H., Chen L., Ai Y., Yang X., Yu Y., Zuo Y., Fu G., 2009. Heavy metal contamination in soil alongside mountain railway in Sichuan, China. Environmental Monitoring 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. http://dx.doi.org/10.1080/02772249909358773.

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

Moret S., Purcaro G., Lanfranco S.C., 2007. Polycyclic aromatic hydrocarbon (PAH) contentof soil and olives collected in areas contaminated with creosote released from old railway ties. Science of the Total Environment 386: 1–8. http://dx.doi.org/10.1016/j.scitotenv.2007.07.008.

Pirrone N., Wichmann-Fiebig M., 2003. Some recommendations on mercury measurements and research activities in the European Union. Atm. Environ. 37: 3–8.

Tikka P.M., Högmander H., Koski P.S., 2001. Road and railway verges serve as dispersal corridors for grassland plants. Landscape Ecology 16: 659–666. http://dx.doi.org/10.1023/A:1013120529382.

UNEP Chemicals, 2002. Global Mercury Assessment. Report no. 54790-01. Geneva, Switzerland. http: //wwww. chem.unep.ch.

Walker C.H., Hopkin S.P., Sibly R.M., Peakall D.B., 2002. Podstawy ekotoksykologii. Wydawnictwo Naukowe PWN. Warszawa .

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. http://dx.doi.org/10.1007/s11270-010-0645-0.

Wittig R., 2002. Ferns in a new role as a frequent constituent of railway flora in Central Europe. Flora 197: 341–350. http://dx.doi.org/10.1078/0367-2530-00050.