Impact of Railroad Transport on Physical and Chemical Properties of Soils in the Railway Junction Zduńska Wola – Karsznice (Central Poland)

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Abstract

Railway operations and the accompanying infrastructure are responsible for the emission of pollutants and toxic substances that adversely affect both the atmospheric air, soil and the groundwater environment. The main groups include such compounds as: trace metals and aromatic hydrocarbons (PAH). Contamination of the soil and water environment with harmful substances can be associated with many activities carried out on the railway. The problem is particularly relevant to liquid fuel loading and refuelling facilities as well as to increased traffic at railway junctions.

The aim of this study was to assess heavy metal contamination of the top soil level of railway areas. The studies were conducted in the area of railway junction Zduńska Wola – Karsznice in central Poland (Łódź Voivodeship). Soil samples were collected from specific research points: from the inter-railway (A), 5 m from the main track (B), from the embankment – 10 m from the main track (C), from the side track (D), at the depth of 0-5 cm and 20 cm. The soil samples were analysed according to laboratory methods generally accepted in soil science. The following analyses were made: granulometric composition – by sieve method, pH in H₂O and conductivity – by potentiometric method, % content of carbonates (CaCO₃) – by Scheibler method. Heavy metals were determined in the fractions: $0.25 \leq 0.5$ mm, $0.1 \leq 0.25$ mm, and $0.05 \leq 0.1$ mm. In soil samples after mineralisation (Anton Paar Multiwave TM 3000 microwave mineralizer), trace metal content was determined: Pb, Cd, Cr, Co, Cu, Mn, Ni, Zn, Sr by inductively coupled plasma mass spectrometry technique (ICP-MS/TOF OPTIMass 9500).

Based on the studied parameters, significant differentiation in soil properties of the areas in Zduńska Wola-Karsznice was found. The analyses carried out showed, among others, accumulation of heavy metals (Pb, Cd, Cr, Co, Cu, Mn, Ni, Zn, Sr) in the topsoil layer, which suggests that the source of these pollutants is mainly railway transport.

Keywords: Trace metals, Soil, Railway area

Introduction

Along with agriculture, industry, and utilities, it is transportation that contributes to a significant increase in pollution levels. Next to road transport, rail is one of the main transport means in the world. In comparison with road transport, the railroads seemed for a long time to be a relatively harmless mode of transport for the environment. This resulted in the fact that most publications were related to studies on soil contamination with heavy metals along roads and highways (Bai et al. 2009; Duong and Lee 2011; Yan et al. 2012; Zhang et al. 2015; Adamiec et al. 2016; Krailertrattanachai et al. 2019). In the last two decades, there has been a significant increase in documentation on environmental hazards and destruction associated with rail transportation (Malawska and Wilkomirski 2001; Gehrig et al. 2007; Zhang et al. 2012; Chen et al. 2014; Wierzbicka et al. 2015; Lucas et al. 2017; Šeda et al. 2017; Stojic et al. 2017; Vaiškūnaitė and Jasiūnienė 2020; Samarska et al. 2020).

An analysis of literature reports indicates that trace metals are among the major pollutants generated in railroad areas. The specificity of these pollutants is that they are not biodegradable and decompose to simple compounds. They have the ability to bioaccumulate and biomagnify. Heavy metals emitted into the environment may migrate from soils to plants, thus there is a risk of their transport to higher trophic levels (Kabata – Pendias and Pendias 1999; Lucas et al. 2017).

The aim of this study was to assess the heavy metal contamination of the topsoil of railroad areas.

Study area

The studies on contamination of the topsoil with heavy metals were conducted in the area of railroad junction Zduńska Wola-Karsznice in central Poland (Łódź Voivodeship) (Fig. 1). According to physico-

geographical division by Kondracki (2002) the area is situated in the south Wielkopolska Lowland macroregion and Łaska Upland mesoregion. The largest part of this area, included in the Łaska Upland, is covered by boulder clays, sands and gravels of glacial accumulation of the Central Poland glaciation.

Fig. 1 Administrative location of the study area (<http://mapa.plk-sa.pl/>).

The railroad junction in Zduńska Wola functions as a junction for freight trains travelling in the direction Wrocław – Silesia – Central Poland. It is located in the south-eastern part of the town (N 51°34'35.47", E 19°00'36.74"), 187 m above sea level (Fig. 1). The 2.6 m wide railroad sleeper (inter-railway width 1.6 m) is made of treated wood. The distance from the second main track is 2.5 m, while the distance from the side track is 7 m.

Methodology

Soil samples for the study were collected from four locations: inter-railway (A) – 5m from the main track, (B) – from the embankment – 10 m from the main track, (C) – from the side track (D). Mineral samples were collected from two depths: 0-5 cm and 20 cm (Table 1).

Table 1. Sampling location.

Designation	Sampling site
A	inter-railway, depth 20 cm
B1	5 m from the main track, depth 0-5 cm
B2	5 m from the main track, depth 20 cm
C1	embankment, 10 meters from the main track, depth 0-5 cm
C2	embankment, 10 meters from the main track, depth 20 cm
D	side track, depth 20 cm

The obtained soil material, after drying to an air-dry state, was analysed in the Environmental Research Laboratory of the Department of Environmental Protection and Management, Jan Kochanowski University in Kielce.

The analysis of soil samples was conducted using generally accepted methods in soil science: granulometric composition – by sieve method, pH in H₂O and conductivity – by potentiometric method, % carbonate content (CaCO₃) – by Scheibler method (Bednarek et al. 2004). Heavy metal determination was

carried out in the fraction of $0.25 \leq 0.5$ mm (medium sand), $0.1 \leq 0.25$ mm (fine sand) and $0.05 \leq 0.1$ mm (very fine sand) (according to PTG 2008). For this purpose, soil samples were dissolved in a mixture of HNO_3 and HCl acids (1:3) and mineralized in an Anton Paar Multiwave TM 3000 mineralizer. The samples were rinsed with deionized water and the contents of heavy metals Pb, Cd, Cr, Co, Cu, Mn, Ni, Zn, Sr were determined in the filtrate using an ICP-MS/TOF OPTIMass 9500 plasma mass spectrometer. Statistical analysis of the data was conducted using Microsoft Office Excel software. Based on the mean geochemical background values developed by Czarnowska (1996), the heavy metal accumulation index (W_n) in the soil was calculated, i.e. the quotient of determined geometric mean content of individual metals and the content in source rocks.

Results

The granulometric analysis showed that the grain size composition of investigated samples varied from one test point to another. Most of the samples showed enrichment in skeletal parts.

The pH values in H_2O ranged from 6.47 (slightly acidic) to 7.29 (slightly basic). The lowest values were found in samples collected from the embankment located 10 m from the main track (6.63-6.46). The highest values were found in soils collected from the side track (7.16-7.29) and the inter-railway (6.8-7.01). The coarse sand fraction ($0.5 \leq 1.0$) and the very fine sand fraction ($0.05 \leq 0.1$ mm) had the highest mean pH values (6.84) while the fine sand fraction ($0.1 \leq 0.25$ mm) had the lowest mean pH value (6.78) (Fig. 2).

In the soils of studied railroad junction, the fraction of very coarse sand ($1.0 \leq 2.0$ mm) had the highest CaCO_3 content (3.89 %) and the fraction of very fine sand ($0.05 \leq 0.1$ mm) 3.97 %, while the fraction of medium sand ($0.25 \leq 0.5$ mm) 0.25 % and coarse sand ($0.5 \leq 1.0$ mm) (0.25 %) had the lowest content (Fig. 2).

Figure 2. CaCO_3 content (%) and pH value in different fractions ($1.0 \leq 2.0$; $0.5 \leq 1.0$; $0.25 \leq 0.5$; $0.1 \leq 0.25$; $0.05 \leq 0.1$ mm) depending on the sampling location. Designations: A (inter-railway, depth 20 cm), B1 (5 m from the main track, depth 0-5 cm), B2 (5 m from the main track, depth 20 cm), C1 (5 m from the main track, depth 20 cm), C2 (embankment, 10 meters from the main track, depth 20 cm), D (side track, depth 20 cm).

The average conductivity value of topsoil samples was $205.34 \mu\text{S} \cdot \text{cm}^{-1}$, the lowest – $116.4 \mu\text{S} \cdot \text{cm}^{-1}$ was found in the coarse sand fraction $0.5 \leq 1.0$ mm (embankment, 10 m from the main track), the highest with a value of $460 \mu\text{S} \cdot \text{cm}^{-1}$ concerned samples collected from the side track (fraction in the range: $0.05 \leq 0.1$ mm).

Table 2. Heavy metal content ($\text{mg}\cdot\text{kg}^{-1}\text{d.w.}$) according to sampling location A (inter-railway, depth 20 cm), B1 (5 m from the main track, depth 0-5 cm), B2 (5 m from the main track, depth 20 cm), C1 (5 m from the main track, depth 20 cm), C2 (embankment, 10 meters from the main track, depth 20 cm), D (side track, depth 20 cm) and fraction diameter ($0.05\leq 0.1\text{mm}$; $0.1\leq 0.25\text{mm}$; $0.25\leq 0.5\text{mm}$).

Sampling location	Depth [cm]	Fraction [mm]	Pb	Cd	Cr	Co	Cu	Mn	Ni	Zn	Sr
$\text{mg}\cdot\text{kg}^{-1}\text{d.w.}$											
A	20	$0.05\leq 0.1$	111.1	0.5	71.8	7.6	1371.9	1848.5	38.1	460.6	115.5
	20	$0.1\leq 0.25$	63.4	0.5	41.4	4.1	636.4	1065.5	22.7	219.8	167.0
	20	$0.25\leq 0.5$	22.3	0.2	21.9	2.1	379.4	986.5	13.2	121.4	61.5
B1	0-5	$0.05\leq 0.1$	60.0	0.2	12.1	2.0	127.2	649.9	10.3	180.7	44.2
	0-5	$0.1\leq 0.25$	30.1	0.1	6.1	1.2	70.5	409.3	6.3	101.4	50.5
	0-5	$0.25\leq 0.5$	16.4	0.0	3.0	0.0	65.3	343.9	0.0	66.9	18.1
B2	20	$0.05\leq 0.1$	174.6	0.4	10.1	5.2	161.9	958.7	24.8	370.8	120.7
	20	$0.1\leq 0.25$	41.9	0.0	6.4	0.0	65.7	540.1	6.3	132.0	86.3
	20	$0.25\leq 0.5$	57.4	0.2	6.3	2.4	80.8	638.9	12.7	147.3	71.8
C1	0-5	$0.05\leq 0.1$	168.1	0.2	9.0	2.1	178.9	602.7	11.2	142.7	75.5
	0-5	$0.1\leq 0.25$	144.1	0.3	7.4	1.6	94.9	414.5	7.5	80.9	71.4
	0-5	$0.25\leq 0.5$	47.4	0.1	3.4	1.0	47.0	282.8	4.5	41.3	32.0
C2	20	$0.05\leq 0.1$	63.0	0.2	8.1	10.4	76.1	1218.8	39.4	98.0	203.8
	20	$0.1\leq 0.25$	30.0	0.1	6.8	7.1	50.8	891.3	29.2	70.4	227.7
	20	$0.25\leq 0.5$	12.4	0.2	7.5	5.4	31.0	721.0	22.2	34.7	195.1
D	20	$0.05\leq 0.1$	68.0	0.2	20.3	2.1	270.5	1601.5	12.5	189.8	92.7
	20	$0.1\leq 0.25$	19.9	0.1	8.3	1.1	76.4	1090.4	6.3	73.2	76.9
	20	$0.25\leq 0.5$	33.7	0.1	10.1	1.2	103.3	1254.3	6.1	101.5	49.2

The study shows that the highest concentrations of elements occurred in samples from the inter-railway (A) and the side track (D). An increase in pollutant concentrations was observed in the embankment 10 m from the track (C), which may be due to the close proximity to the road. The lowest element concentrations were recorded 5 m from the main track (B).

The average concentration of Pb was $64.6\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$ ($12.4 - 174.6\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$). The highest Pb concentrations were found in samples A, B2 and C1, while the lowest concentrations were found in C2. The highest concentration of Cd was found in samples A ($0.5\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$), with no Cd recorded in B1 and B2 ($0\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$). Higher cadmium values were found in $0.05\leq 0.1\text{mm}$ fraction. The mean Cr concentration was equal to $14.5\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$, the maximum, $71.8\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$, was recorded in samples A, while the minimum was $3.0\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$ in B1. The Co content ranged from 0 (B1, B2) to $10.4\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$ (C2). Concentrations were comparatively low at the other sites. In the topsoil, the mean copper content was $216.2\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$, the maximum $1371.9\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$ (A), while the minimum was $31.0\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$ (C2). The highest concentrations of Cu were recorded in the inter-railway, and the values decreased with distance from the track. The study shows that the average Mn content was $862.1\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$, with minimum $282.8\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$ (C1), and minimum $1848.5\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$ (A). High concentrations were also recorded in samples D. For manganese, there was a correlation between concentration and depth. At a depth of 20 cm, higher Mn contents were recorded than in samples from the 0-5 cm level. The mean Ni concentration was equal to $15.2\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$, with a maximum of $39.4\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$, recorded in C2 and was most likely due to proximity to the road. A similar value to the maximum equal to $38.1\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$ was also recorded in A, while no Ni was found in B1 samples. The mean Zn content was $146.3\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$ with highly significant variation in results between sites. The minimum and maximum values were $34.7\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$ and $460.6\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$, respectively. The highest concentration of zinc in the substrate was found in samples A as well as B1 and B2. The Sr content ranged from 18.1 (B1) to $227.7\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$ (C2), with a mean of $97.8\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$ High concentrations were also recorded in the inter-railway ($167.0\text{ mg}\cdot\text{kg}^{-1}\text{d.w.}$) (Fig. 3).

Figure 3. Ranges of metals tested in soil samples.

Based on the mean geochemical background values developed by Czarnowska (1996), an index of heavy metal accumulation (Wn) in the soil was calculated (Table 3).

Table 3. Heavy metal accumulation index in soil samples.

Sampling location	Index of heavy metal accumulation							
	Pb	Cd	Cr	Co	Cu	Mn	Ni	Zn
Inter-railway	6.7	22.2	1.7	1.1	112.1	4.5	2.4	8.9
5 m from the main track	6.5	5.5	0.3	0.4	13.4	2.0	1.0	5.5
10 meters from the main track	7.9	11.1	0.3	1.1	11.2	2.4	1.9	2.6
Side track	4.1	5.5	0.5	0.4	21.3	4.5	0.8	4.0

The accumulation index values for Pb, Cd, Cr, Co, Cu, Mn, Ni, Zn ranged from 0.3 (for Cr) to 112.1 (for Cu). It should be noted that the highest accumulation index values of Wn=22.2 for cadmium; Wn=1.7 for chromium; Wn=1.1 for cobalt; Wn=112.1 for copper; Wn=4.5 for manganese; Wn=2.4 for nickel and Wn=8.9 for zinc were found in the samples from the inter-railway, while the highest accumulation index of Wn=7.9 for lead was found in the samples collected 10 m from the track. The mean accumulation index values in the investigated soils were arranged in the following series Cu>Cd>Pb>Zn>Mn>Ni>Co>Cr.

Discussion of results

The topsoil levels in the railroad areas in Zduńska Wola are contaminated with lead, cadmium, chromium, cobalt, copper, manganese, nickel, zinc and strontium. Similar conclusions are found in foreign papers e.g. Liu et al. 2009; Chen et al. 2014; Zhang et al. 2012; Zhang et al. 2015; Lucas et al. 2017; Šeda et al. 2017; Stojic et al. 2017; Vaiškūnaitė and Jasiūnienė 2020; Samarska et al. 2020) and in Poland (Malawska et al. 2001; Wilkomirski et al. 2011; Wilkomirski et al. 2012; Józwiak et al. 2013). Contaminants accumulate in the near-surface soil horizon.

According to Kabata-Pendias et al. (1999), the limiting content of heavy metals in soils containing only anthropogenic pollutants is for Cd 1, Cu 25, Ni 50, Pb 70, Cr 100, Zn 150, Mn 1000 mg·kg⁻¹. Comparing the obtained results with the limiting values of heavy metals accumulated in anthropogenic soils according to

Kabata-Pendias et al. (1999), it was established that mean concentrations of heavy metals in samples from Zduńska Wola were exceeded for Cu (at each sampling point), Mn (inter-railway, side track), Zn (inter-railway, 5 m from the track) and Pb (10 m from the track).

In the operational sphere, trains are susceptible to destructive environmental influences (i.e. atmospheric factors causing corrosion and damage due to lightning, ultraviolet radiation and temperature changes; human activity). All of these factors contribute to the formation of specific wastes that lead to soil contamination. These include e.g. damaged and worn out elements of the vehicle, polluting substances accumulated on the vehicle, waste created in the process of disinfecting compartments, toilets and in the process of heating, ventilating, cleaning, used technical liquids (oils, greases, hydraulic liquids) and in case of freight cars – the remains of transported loads (e.g. wood, cement, coal, liquid chemical products), sludge from domestic and sanitary wastewater (organic and inorganic particles, detergents, soaps, paper, disinfectants, faecal matter) and vapours of solvents, sulphuric and oxalic acid emitted into the atmosphere. Generally, the waste contains steel (Fe, C), non-ferrous metals (Al, Mg, Ti, Cu, Zn, Ni, Pb, Cd), rubber, plastics, chemicals, and glass. Oil and hydraulic fluids leaking from shock absorbers, discs, buffer bushings, draw hook guides and grease (Ca, Cu, Al, Li) found on the current collectors of electric locomotives pulling wagons also contribute to soil pollution (Malawska et al. 2001; Moczarski 2006; Liu et al. 2009; Wilkomirski 2010; Wilkomirski et al. 2011; Józwiak et al. 2013). Antunias et al. (2004) also showed that herbicides used for conservation purposes on railroad lands contribute to soil degradation.

According to Chillrud et al. (2005) and Moczarski (2006), iron oxides, which are formed from oxidized cast iron brake blocks, wheelset rims, brake discs, and from corroded fragments of railroad cars, and copper oxides formed from oxidized power collectors and catenary lines are among the compounds that cause soil contamination (Chillrud et al. 2005; Moczarski 2006). This thesis is supported by the present study. The highest concentration of Cu was detected in the area of rails. According to Wilkomirski et al. (2012), this is a result of intensive operation of pantographs by rail vehicles, which are used to collect current from the overhead catenary wires.

Analyzing the study of Samarska et al. (2020), the Fe content in soil samples from railroad areas was strongly correlated with Ni, Cr and Mn content. The values of element concentrations in the studied soils were arranged in the following order: Fe > Mn > Cu > Cr > Ni > Zn > Pb > As. These metals are components of railroad steel, as noted by Samarska et al. (2020), and may be derived from rail and wheel abrasion.

According to Liu et al. (2009), the Mn comes from wheel and rail abrasion, while Pb and Cd from automobile emissions. Therefore, the authors claim that the abrasion of train bodies and the discarding of waste by travelers can be a source of heavy metals in the soils of railroad areas. Similar observations were made by Vaiškūnaitė & Jasiūnienė (2020), who found that the highest concentrations of Pb and Cd were recorded at a distance of 5.0 m from railroad sleepers in the upper (up to 10 cm) layer of soil.

The study of Łukasiewicz (2011), showed that lead was present in the upper part of the profile at 6 of 21 sites, while deeper at 19 sites already. This is not consistent with the results presented in the paper. The study does not support the thesis that Pb concentration increases with the depth of soil profile.

Cadmium was characterized by the lowest concentration in the studied soil samples. Concentration of this element does not show any change depending on the depth of sampling. It is accumulated both in shallower and deeper soil profiles. The investigated soil samples contain high concentrations of manganese, which sorbs cadmium, thus decreasing its mobility in the environment and availability to the flora. The content of Mn and Zn does not show a strong correlation with the depth of sampling, which confirms that Mn and Zn are common elements and their content in soil strongly depends on the content in the source rock (Rapalska 2010). While, the presence of lead is largely the result of anthropogenic activity rather than the result of source rock. Liu et al. (2009) argue that high organic matter content may contribute to heavy metal retention in the immediate vicinity of railroad areas.

The effect of a busy railroad line in Zurich on the amount of heavy metal emissions was the subject of Bukowiecki et al. (2007). The results clearly show that more than half of the iron and manganese from wheel and rail abrasion are particles of size 2.5-10 mm.

The study conducted by Liu et al. (2009) in China shows that heavy metals, the emission of which is particularly associated with rail transport, are zinc, copper and manganese that is consistent with the observations conducted in Zduńska Wola. As noted by Stojic et al. 2017, the concentration values of Cu, Ni, Cd, Pb in samples collected from up to 1 km from the railroad line were higher than in samples collected from > 1 km, which is consistent with the research conducted in Zduńska Wola.

Chen et al. (2014) conducted a study near Suining railroad station, Sichuan province, China. They sampled a newly constructed railroad line and lines in operation for 5, 9, and 15 years. According to Chen et al. (2014), the concentration levels of Zn, Cu and Fe in soil samples are not affected by anthropogenic activities, soils were contaminated with Cd and Pb, and their maximum content was determined in samples from railroad areas with the longest operating time. Similar conclusions were drawn by Chen et al. (2014) concluding that lead

and cadmium in soils from railroad sites mainly comes from anthropogenic activities i.e., leaks from railcars and dust emissions from transported materials. As noted by Chen et al. (2014), the level of Cd and Pb contamination decreased along with increasing distance from the rail. Similar findings are presented in this paper, with Cd and Pb contamination levels again increasing in samples collected along the community road. A good sampling practice was followed by Zhang et al. (2015), who conducted a study on the world's highest railroad line Qinghai-Tibet. To avoid any influences from the highway, samples were collected from a railroad track located away from the highway. The authors found that the concentrations of V, Co and Rb were the same in each sample, while the values of Zn, Cd and Cd in the samples from the embankment were seven times higher than the geochemical background of study area. Zhang et al. (2012) and Zhang et al. (2015), also observed that landform is the most probable cause of differences in the concentrations of heavy metals such as Pb, Zn and Cd.

Studies conducted by Malawska et al. (2000) on railroad areas in Tarnowskie Góry show that the level of heavy metal contamination near railroad sites decreased with increasing distance from the rails, which is consistent with the results presented in this paper. Malawska et al. (2001) also state that transport of goods, which contain harmful water-soluble substances, contributes to soil contamination in railroad areas. This is even more dangerous in the case of trains that remain in one place for a long time.

Malawska et al. (2001) and Wilkomirski et al. (2012) in their papers determining the content of heavy metals in soil and plant samples collected from railroad sites (Iława Główna) concluded that railroad transport can be a significant threat to the environment. This refers to both organic and inorganic pollutants. The content of heavy metals is higher in the area of the rolling stock cleaning bay and the railroad siding, while the areas of goods handling station and the platform were less contaminated. The study found high contents of iron, cobalt, zinc and chromium in samples collected from the rolling stock cleaning bay and high contents of Cu, Mn and Zn at different parts of the railroad junctions. Comparing the scientists' data with the results from Zduńska Wola, it should be stated that the content of the mentioned elements was also at the highest level, with particular emphasis on Mn.

Conclusion

The high level of heavy metal contamination of soils in railroad areas can have a destabilizing effect on ecosystems. The study found that the pH values of investigated soils ranged from 6.47 (slightly acidic) to 7.29 (slightly alkaline). With increasing distance from the rails, the pH value decreased. The average concentrations of particular metals in the soil of railroad junction in Zduńska Wola were as follows: Mn>Cu>Zn>Sr>Pb>Ni>Cr>Co>Cd. Higher trace metal contents were found in the very fine sand fraction ($0.05 \leq 0.1$ mm). The highest concentrations of heavy metals were recorded in samples collected from close to the rails (inter-railway, side track), and in the embankment (10 m from the track). The mean values of accumulation index in the investigated soils were arranged in the following series Cu>Cd>Pb>Zn>Mn>Ni>Co>Cr. The high accumulation index of copper, cadmium and lead in the surface layer of soil indicate their anthropogenic origin.

Conflicts of Interest: The authors declare no conflict of interest.

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