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SULPHUR IN SOILS WITHIN THE IMPACT ZONE OF THE METALLURGY-SULPHUR RAILROAD IN THE ROZTOCZAŃSKI NATIONAL PARK

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A b s t r a c t. The aim of the research was to evaluate the influence of the metallurgy-sulphur railroad (LHS) on some soil properties of the Roztoczański National Park. Special attention was paid to sulphur risks, due to sulphur transport that way, although in smaller quantities as compared to the previous decade. The study was based on the analysis of basic properties of selected soils and content of total and sulphate sulphur in soil samples taken in 2 cross-section profiles, located 400 and 900 m from the border of the Park and 50, 100, and 150 m from the rails; from 3 levels of forest soils: litter, 0-10 cm, and 30-40 cm. Pedological survey indicated that within the study area predominated light soils. They are derived from river sands (mainly gley, gley-podzolic, podzolic soils, and black earth), and contain low amounts of the fine fraction. It was found that the line, which runs across the protected areas of the national park, does not exert nowadays a direct negative influence on the investigated soil properties (C-organic, reaction, mobile aluminium). The amount of total and sulphate sulphur remains on the level characteristic for such soil types in natural environment. No decrease in the content of both forms of sulphur was found along with the distance of sampling points from the LHS rails.

K e y w o r d s: sulphur deposit, soil response, metallurgy-sulphur railroad, protected areas.

INTRODUCTION

According to the Law of Nature Protection in Poland [18], the main task of the national park is to recognize and to preserve natural systems of a specific area, as well as to reconstruct deformed and disappearing components of native nature. Thus, all activities within the national parks should aim at nature conservation and should be undertaken prior to any other activity. Unfortunately, this regulation has not always been obeyed in the past. That is why in many regions of Poland, including the Lublin region, nature is threatened by serious anthropogenic factors. The Metallurgy-Sulphur Railroad (Linia Hutniczo-Siarkowa-LHS), led through the Roztoczański National Park (RPN) is a very spectacular example of such mistakes [2].

The operation of that line, according to many specialists, affects the unique natural environment of the Park [2,7,16]. It is a "line-surface" source of elementary sulphur which finally reaches plants and soils. The studies carried out during a very intense transport of sulphur *via* that line in 1990 indicated that almost 2 tons of sulphur spread from the train carts yearly at the distance of 1 km within the Park. It was also found that elementary sulphur, coming from LHS transports, occurred at the distance of about 120-140 m on both sides of the rails. It was calculated that its contribution to soil acidification in that area of the Park was about 30 %. Increased content of sulphur in pine needles was also stated [2].

Acidification due to acid-forming gaseous air pollutants, mainly sulphur (IV) oxide SO_2 and nitrogen oxides NO_x is of great importance for environment protection, agriculture and forestry, and especially for protected areas. Despite the fact that emission of sulphur oxide in Poland has recently been clearly reduced, still in many areas it significantly contributes to natural processes of soil acidification [4]. It should be stressed that Poland is characterized by very high emission and immission levels of sulphur oxide as compared to other OECD countries [6]. According to various sources, from a few to several hundred kilograms of SO_2 reach the soil over 1 ha per year [5,8,9,11].

Sulphur oxides emitted to atmosphere act immediately on soil acidification because they form strong acids when dissolved in water. The effects of SO_2 acidification can be met far away from the emitter. Elementary sulphur acidifies soil after sulphur oxidation. The effects of acidification with this form of sulphur are usually of local character. Studies carried out by Motowicka-Terelak and Terelak [10,12] showed that enrichment of surface and subsurface soil layers with sulphur as an impact of high SO_2 emissions had significantly contributed to soil acidification, and it had increased with the increase of sulphur immission. For the sandy soil it ranged from 25 to 87%, while for the loamy one form 22 to 100%. Decrease in soil reaction depended on the sulphur dose (immission rate), period of contamination and soil type. Due to many-year soil contamination with sulphur, unfavourable changes were also recorded in the ionic composition of the soil sorption complex; decrease of Ca and Mg amounts and increase in the concentration of mobile forms of aluminium. Many other studies confirm the above statements [8].

Despite the fact that many studies were undertaken up-to-date to estimate the effects of sulphur pollution on the soil, no clear answer has been obtained so far

[1,8-13]. That is because sulphur contamination effects overlap with often unfavourable other soil conditions, actual natural acidification processes, faulty fertilization measures, etc. [3,4,14,15].

Strong soil acidification due to excessive sulphur fallout creates unfavourable, very often toxic conditions for the majority of plants. Apart from soil reaction, also a sharp deficiency of mineral nutrients occur, often accompanied by mobilized phytotoxic elements and heavy metals [8,11].

Therefore the aim of the research was to evaluate the influence of LHS on some properties of the soils of that region, with special emphasis on sulphur risks, which is still transported that way, although in smaller quantities nowadawys as compared to the previous decade.

STUDY AREA AND METHODS

The studies were performed in the Roztoczański National Park, within the physiographic region called Middle Roztocze. It covers the area of 8,482 ha, and together with protection zone has about 38 000 ha. This area is characterised by the strong impact of continental climate; i.e. long winter and summer periods (over 100 days). In this region there is the highest number of sunny and cloudless days in Poland. Mean annual temperature is 7.3 ^{o}C and annual precipitation exceeds 650 mm.

Picturesque landscape is formed by forest strip hills, built-up from the Upper Cretaceous chalks, gaize and marls. Wide valleys are covered with a thick layer of post-glacial sands. Rare younger tertiary formations, mainly sandstones occur on tops of monadnocks.

Specific geological structure, water regime and relief had a decisive effect on the differentiated soil cover of the Park. Cambisols, Luvisols and Rendzinas dominate on hill tops and slopes, while in valleys Podzols are dominant. There are also Fluvisols and Phaeosems in river valleys [19]. All abiotic and soil conditions resulted in a great number of plant associations, some of them being very rare and under careful protection. Through this unique nature reserve a railroad was built in 1979, which connected iron ore centre in Ukraine and Russia with sulphur mines in Central Poland and steel works and coal mines in the Upper Silesia. In some years the total tonnage of train loads (iron and manganese ore, hard coal and sulphur) reached 6.5 million tons per year (e.g. sulphur 2,600 tons, coal 4,800 tons, and iron ore 12,100 tons per day). It resulted in environment contamination with the above materials to the level harmful to nature [2,7,16].

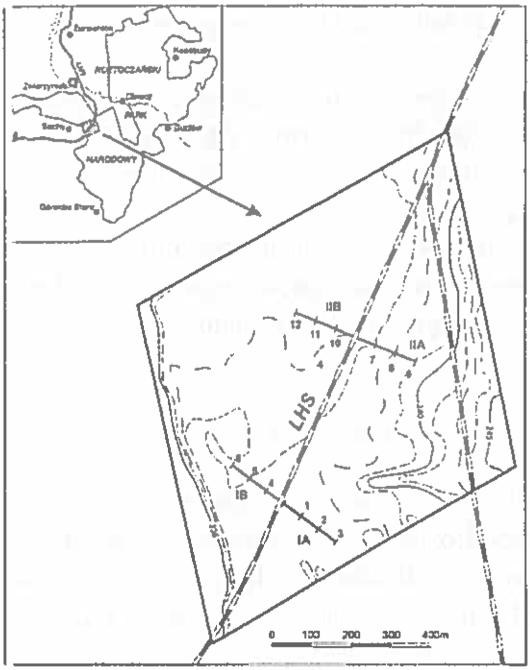

Fig. 1. Study area and location of cross-sections and soil profiles.

The research was based on the analysis of basic properties of selected soils and content of total and sulphate sulphur in soil samples taken in 2 cross-section profiles, located 400 and 900 m from the border of the Park and 50, 100, and 150 m from the rails; from 3 levels of mixed forest soils: litter horizon, the surface layer of 0-10 cm, and the layer of 30-40 cm (Fig. 1).

In soil samples, the following analyses were performed: organic C with Tiurins method, organic substance after Lityński, pH in water and 1 M KCl, grain size distribution acc. to Casagrande method as modified by Prószyński, mobile aluminium after Sokolov, total sulphur nephalometrically, and sulphate sulphur after Ensminger.

RESULTS

The results of pedological survey indicated that the soils in the selected sites represented light soils derived from river light sands (mainly gley, gley-podzolic, podzolic soils, and black earth), which had low contents of the fine fraction and differentiated thickness of the litter (Table 1).

It was found that the contents of both forms of sulphur were not high as compared to the literature data concerning the occurrence of these elements in similar soils. Also, changes in total sulphur and sulphate form did not show any regularities as far as the distance from the rails was concerned (Table 2).

The highest amounts of total sulphur (212.5 mg S_{tot}/100 g soil) were found in

Table 1. Characteristics of soils and soil samples collected from two cross-sections in the vicinity of Metallurgy-Sulphur Railroad in the Roztoczański National Park

Soil sample	Cross-section	Soil profile* No. and distance to rails	Genetic horizon	Sampling depth (cm)	Grain size distribution (%)		
					1-0.1	0.1-0.02	<0.02
					(mm)		
1			O	2-0	0	0	0
2	IA	1-50 m	A	0-10	85.4	10.6	4.0
3			C1gg/C2gg	30-40	95.1	3.9	1.0
4			O	2-0	0	0	0
5	IA	2 - 100 m	A1	0-10	86.6	9.4	4.0
6			A3	30-40	86.5	10.5	3.0
7			O	3-0	0	0	0
8	IA	3- 150 m	A1	0-10	90.0	7.0	3.0
9			A2Cgg	30-40	94.0	3.0	3.0
10			O	1-0	0	0	0
11	IB	4 - 50 m	A1	0-10	64.2	30.8	5.0
12			A2Cgg	30-40	86.0	9.0	5.0
13			O	2-0	0	0	0
14	IB	5 - 100 m	A1	0-10	69.4	25.6	5.0
15			A2Cgg	30-40	82.7	13.3	4.0
16			O	8-0	0	0	0
17	IB	6 - 150 m	A	0-10	85.1	10.9	4.0
18			Ees	30-40	91.3	6.7	2.0
19			O	8-0	0	0	0
20	IIA	7 - 50 m	A	0-10	75.3	21.7	3.0
21			Bfe/BfeC	30-40	77.9	19.1	3.0
22			O	8-0	0	0	0
23	IIA	8 - 100 m	A	0-10	80.3	15.7	4.0
24			Bfe	30-40	81.8	14.2	4.0
25			O	8-0	0	0	0
26	IIA	9 - 150 m	A	0-10	84.1	11.9	4.0
27			Bfe	30-40	84.8	11.2	4.0
28	IIB	10 - 50 m	O	11-0	0	0	0
29			A	0-10	75.0	18.0	7.0
30			O	8-0	0	0	0
31	IIB	11 - 100 m	A	0-10	84.2	12.8	3.0
32			Box	30-40	87.5	9.5	3.0
33			O1	10-5	0	0	0
34	IIB	12 - 150 m	O2	5-0	0	0	0
35			A	0-10	83.3	12.7	4.0
36			Eesgg	30-40	88.9	7.1	4.0

*Soil types acc. to FAO-UNESCO: 1 and 10 - Arenic Gleysols; 2,3,4 and 5 - Mollic Gleysols; 6 and 11 - Gleyic Podzols; 7,8,9 and 12 - Humic Podzols. All soils were derived from loose river sands, except soil No. 10, derived from weakly loamy river sands.

litter accumulation horizon of profile No. 5 (cross-section I), located 100 m from the rails. The lowest amount (106.25 mg S_{tot}/100 g soil) was in the litter horizon of profile 2, 100 m from the rails opposite to profile 5. The content of total forms of sulphur tended to decrease with the profile depth (Fig. 1).

The content of sulphate forms of sulphur ranged from 1.5 mg $S\text{-}SO_4$/100 g soil

Table 2. Chemical and physicochemical properties of the studied soils

Soil sample*	pH		$C_{org.}$ (%)	Organic matter (%)	Exchan. Al me Al^{3+}/100 g soil	S-SO_4 mg/100 g soil	S_{tot} mg/100 g soil
	H_2O	1 M KCl					
1	5.58	4.86	-	40.65	0.08	3.75	156.25
2	5.13	4.33	1.74	-	0.02	1.125	18.75
3	6.05	5.31	0.06	-	0	0.375	3.75
4	5.25	4.67	-	42.0	0.08	4.25	106.25
5	5.32	4.51	1.80	-	0.03	0.875	28.75
6	5.61	4.91	1.92	-	0	0.750	21.25
7	4.63	3.83	-	33.97	0.52	5.25	206.25
8	4.76	3.82	0.96	-	0.20	0.50	10.00
9	6.08	5.19	0.11	-	0	0.50	6.25
10	5.71	5.03	-	41.67	0	5.00	187.50
11	5.21	4.41	6.18	-	0.05	0.875	62.50
12	5.87	5.03	0.72	-	0	0.50	15.00
13	5.14	4.45	-	71.18	0	3.50	212.50
14	4.87	4.10	6.24	-	0.09	0.875	70.00
15	5.64	4.96	1.44	-	0	0.50	23.75
16	3.75	2.88	-	61.26	2.16	1.75	137.50
17	3.49	2.94	2.64	-	1.17	0.50	11.25
18	3.82	3.34	0.45	-	0.60	0.375	3.75
19	3.65	2.75	-	66.99	2.84	2.25	181.25
20	3.78	3.04	1.44	-	1.30	1.00	21.25
21	4.56	4.33	0.66	-	0.85	1.25	10.00
22	3.84	2.99	-	74.94	3.28	2.75	156.25
23	3.67	2.91	0.93	-	0.63	0.875	6.25
24	4.27	4.35	0.35	-	0.64	4.625	20.00
25	3.60	2.81	-	75.11	4.56	2.75	175.00
26	3.80	3.01	0.66	-	0.87	0.75	7.50
27	4.78	4.43	0.35	-	0.57	0.75	6.25
28	3.37	2.69	-	74.15	7.48	1.50	155.25
29	3.68	3.29	2.82	-	3.00	1.125	13.75
30	3.82	2.95	-	70.96	4.27	1.50	181.25
31	3.83	3.02	1.14	-	1.09	0.375	6.25
32	4.43	4.04	1.56	-	1.80	0.75	10.00
33	3.59	2.77	-	78.52	4.55	3.00	175.00
34	3.27	2.52	-	60.76	7.88	1.50	155.25
35	3.77	2.96	1.50	-	0.71	0.375	8.75
36	4.17	3.50	0.12	-	0.35	0.250	3.75

*Description of soil samples as in Table 1.

(e.g. litter horizon in profile No. 10, 50 m from rails) to 5.25 mg S-SO_4/100 g soil (profile 3, 150 m from rails). In mineral soils it was from 4.72 mg S-SO_4/100 g soil (layer 30-40 cm in profile 8, 100 m from rails), to 0.25 mg S-SO_4 in profile 12, 150 m from rails (Fig. 1).

The results of soil reaction indicate that most soils can be classified as very acid or acid (pH_{KCl} 3.5-5.5 for forest soils). In general, soils from the cross-section I show reaction higher by 1 unit than soils from the cross-section II. Significant differences occur between the reaction of surface layers as compared to deeper ones, the latter being much higher.

The contribution of organic matter in litter horizons was very high (from almost 34-71% in soils of the cross-section I to 61-78% in soils of the cross-section II).

The content of organic carbon ($C_{org.}$) did not exceed 3% in mineral horizons, except surface horizons of profiles 4 and 5 (6.18 and 6.24%, respectively).

Also, the contents of mobile aluminium in soils of the cross-section I were at a very low level (from 0 do 0.52 me Al^{3+}/100 g soil). Only organic horizons and surface horizons of gley-podzolic soils showed high amounts of mobile aluminium (about 2 me Al^{3+}/100 g soil). Soils of the cross-section II showed much higher levels of this element.

It can be concluded that the decreased activity of the metallurgy-sulphur railroad has a much lower impact on the soil cover of the Roztoczański National Park, as compared to its effects in the Eighties [2,16]. The area of native sulphur occurrence in the neighbouring soils has been decreased (it did not exceed 50-meter strip from the rails, in comparison to 140 m in the past). The average contents of sulphate sulphur were also much lower in the present study as compared to those performed 10 years ago. Soil reaction remained within the level typical for forest soils derived from weak and loose sands.

CONCLUSIONS

1.The results of pedological survey indicated that the soils in the selected sites represent light soils derived from river light sands (mainly gley, gley-podzolic, podzolic soils, and black earth), which had low contents of the fine fraction and differentiated thickness of the litter.

2.The Metallurgy-Sulphur Line (LHS), which runs through the protected areas of the Roztoczański National Park, does not have a direct negative influence nowadays on the investigated soil properties (C-organic, reaction, mobile aluminium).

3.The content of total and sulphate sulphur in the soils is not elevated but characteristic for such type of soil in the natural environment. No decrease in the content of both forms of sulphur was stated along with increasing the distance of sample taking points from the LHS rails.

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