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THE MICROBIAL ACTIVITY OF SOILS LOCATED IN THE NEIGHBOURHOOD OF THE SALT MINE IN KŁODAWA VS SELECTED CHEMICAL PROPERTIES

Summary

The article presents the results of a study of microbial properties of soils influenced by emissions from the salt mine in Kłodawa vs salinity parameters. 15 medium-sized surface soil samples were collected from fields adjacent to the salt mine. The following parameters were measured in the samples: the content of water-soluble cations, pH, electrolytic conductivity, the content of carbon and nitrogen, salinity parameters – Z and SAR indexes. The following microbial properties were measured: total count of bacteria, fungi and actinobacteria and the enzymes activity. The soils under analysis were classified as luvisols soils of the good wheat complex and very good rye complex. The content of total carbon ranged from 0.86% to 5.72%, whereas the content of nitrogen ranged from 0.09% to 0.52%. Their pH was mostly alkaline and ranged from 6.25 to 8.16. It was impossible to classify them as saline soils according to the research findings and calculated parameters. There were higher values of electrolytic conductivity, Z and SAR indexes and the content of water-soluble sodium in the samples collected from direct neighbourhood of the source of emission. The research did not reveal any significant influence of higher, though diversified salinity of soils in the neighbourhood of the salt mine in Kłodawa on the count of basic groups of microorganisms and the enzymatic activity at their accumulation and humus levels. The microbial and biochemical parameters were more influenced by the content of organic matter, pH in the surface soil layers and species of plants grown rather than higher salinity. In most cases the most favourable edaphic conditions for the growth and development of microorganisms were in the epipedons under grassland and plantations of leguminous crops, especially red clover.
***Key words**: salinity, electrolytic conductivity, Z and SAR coefficients, enzymatic activity, microbial activity*

AKTYWNOŚĆ MIKROBIOLOGICZNA GLEB POŁOŻONYCH W SĄSIEDZTWIE KOPALNI SOLI W KŁODAWIE NA TLE WYBRANYCH WŁAŚCIWOŚCI CHEMICZNYCH

Streszczenie

W pracy przedstawiono wyniki badań dotyczące właściwości mikrobiologicznych gleb będących pod wpływem emisyjnego oddziaływania kopalni soli Kłodawa na tle parametrów charakteryzujących stopień zasolenia. Do badań pobrano 15 średnich próbek powierzchniowych z pól przyległych do kopalni soli. W pobranych próbkach glebowych oznaczono zawartość kationów rozpuszczalnych w wodzie, odczyn, przewodnictwo elektrolityczne, zawartość węgla i azotu, oraz wyliczono parametry charakteryzujące stopień zasolenia takie jak współczynnik „Z" i SAR. Oznaczono także właściwości mikrobiologiczne takie jak: ogólną liczebność bakterii, grzybów i promieniowców oraz stężenie enzymów. Analizowane gleby zaliczono do gleb płowoziemnych, kompleksu pszennego dobrego i żytniego bardzo dobrego. Zawartość węgla ogólnego mieściła się w przedziale od 0,86 do 5,72%, azotu od 0,09-0,52%. Ich odczyn był w większości zasadowy a jego wartości wyrażone w jednostkach pH mieściły się w przedziale od 6,25-8,16. Uzyskane wyniki badań oraz wyliczone parametry nie pozwalały zaklasyfikować analizowanych gleb do zasolonych. Wyższe wartości przewodnictwa elektrolitycznego, wskaźnika „Z", SAR oraz zawartości sodu rozpuszczalnego w wodzie stwierdzono w próbkach pobranych w bezpośrednim sąsiedztwie źródła emisji. Nie stwierdzono istotnego wpływu podwyższonego, choć zróżnicowanego, zasolenia gleb położonych w sąsiedztwie Kopalni Soli Kłodawa na liczebność podstawowych grup drobnoustrojów i aktywność enzymatyczną panującą w ich poziomach akumulacyjno-próchnicznych. Wspomniane parametry mikrobiologiczno-biochemiczne zależały bardziej od zawartości materii organicznej i odczynu określonego w poziomach wierzchnich oraz gatunków uprawianych roślin, niż podwyższonego zasolenia. W większości przypadków najkorzystniejsze warunki edaficzne dla wzrostu i rozwoju mikroorganizmów występowały w epipedonach pod użytkami zielonymi oraz uprawą roślin bobowatych, głównie koniczyny czerwonej.
***Słowa kluczowe**: zasolenie, przewodnictwo elektrolityczne, współczynnik Z oraz SAR, aktywność enzymatyczna, aktywność mikrobiologiczna*

1. Introduction

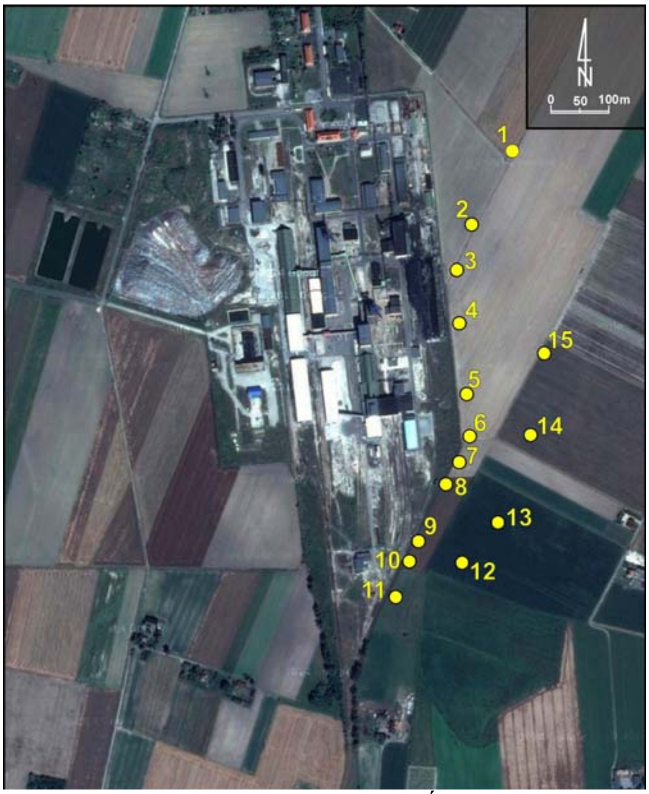
The exploitation of natural resources often involves changes in soil properties, which are manifested by excessive salinity of the environment caused by substances from landfills and spoil tips of waste from the sodium industry as well as metallurgical and furnace waste [29, 30, 38]. Increased salinity causes not only ion imbalance in soil, but it also reduces soil permeability and changes its pH. Excessive concentration of salt in a soil solution has negative influence on microbial life, as it increases osmotic pressure and prevents the uptake of water. As a result, the development of microbial cells is arrested, causing the death of microorganisms [38]. Microorganisms are one of the most important determinants of soil fertility and bioproductivity. The greatest amounts of microorganisms can be found in the arable layer and around plants' roots – in the rhizosphere. The microorganisms surrounding plants' roots are strictly related with the plant species [21, 40]. Microbial properties are also to different extents influenced by the method of soil use as well as the species, cultivar and phase of growth of crops [14, 18, 32, 44, 19, 34].

The aim of the study was to specify the parameters characterising the microbial activity of soils under different influence of emissions from the salt mine in Kłodawa.

2. Materials and methods

Medium-sized samples of soils (30-40 punctures per plot) were collected from a depth of 0-20 cm from farmlands located in the zone of emissions from the salt mine in Kłodawa. Fig. 1 shows the sites from which the samples were collected. According to the current taxonomy, the soils were chiefly classified as lessive soils of the good wheat complex and very good rye complex. The total content of carbon and nitrogen was measured in air-dry soil layers by means of elementary analysis with a Vario-Max apparatus. A water extract at a 1:1 water/soil ratio (v/m) was also prepared to measure electrolytic conductivity, pH and the content of ions Ca^{2+} , Mg^{2+}, K^{+} and Na^{+}. The results were used to calculate salinity indexes, i.e. SAR (Sodium Adsorption Rate) and Z.

Microbial parameters were measured in freshly collected soil samples, such as the count of basic soil microorganisms on adequate selective substrates measured with the plate method. The total count of colony forming units (CFUs) of heterotrophic bacteria, actinobacteria and fungi was measured. The count of heterotrophic bacteria was measured on a standard agar medium (Merck) after 24-hour incubation at 35°C. The count of moulds was measured on a Martin substrate [23] after 5-day incubation at 24°C. The count of actinobacteria was measured on a selective Pochon substrate [15], where the plates were incubated for 7 days at 26°C.



Source: own work / *Źródło*: praca własna

Fig. 1. The location of research sites

Rys. 1. Lokalizacja punktów badawczych

Apart from that, the spectrophotometric method was used to measure the enzymatic activity of dehydrogenase. The dehydrogenase activity was measured by means of a 1% triphenyltetrazolium chloride (TTC) substrate and 24-hour incubation at 30°C. According to Thalman's method, the dehydrogenase activity was expressed as TPF micromoles per 1 g of dry weight of the substrate within 24 hours [39]. The alkaline phosphatase activity was measured according to Tabatabai and Bremner's method [37] by means of an 0.8% solution of sodium p-nitrophenyl phosphate as a substrate and 1-hour incubation at 37°C. The enzyme activity was expressed as PNP$\cdot$ $kg^{-1} \cdot h^{-1}$ (p-nitrophenol per 1 kg of soil per 1 hour). The urease activity was determined according to Zantua and Bremner's [45] method, where a 2.5% urea solution was used a substrate. The incubation at 37°C lasted 18 hours. The enzyme activity was expressed as mg $N\text{-}NH_4^+ \cdot kg^{-1} \cdot h^{-1}$ (per 1 kg of soil per 1 hour). The protease activity was measured according to Ladd and Butler's [20] method, where a 1% sodium caseinate, pH 8.1 was used a substrate. The incubation at 50°C lasted 1 hour. The enzyme activity was expressed as mg tyrosine $kg^{-1} \cdot h^{-1}$ (per 1 kg of soil per 1 hour). There were three replications of all measurements. The results were averaged.

3. Results and discussion

Table 1 shows the results of chemical properties of the soil samples under analysis. The content of total carbon ranged from 0.86% to 5.72%. The highest content was found in the soil samples collected from the permanent grassland, sites 10 and 11 – 2.91% and 5.72%, respectively. The content of total nitrogen was also diversified and ranged from 0.09% to 0.52%. Similarly to carbon, the highest content was found in the samples collected from the permanent grassland. The carbon/nitrogen ratio, which is used to determine bioactivity, was relatively narrow and ranged from 8.7 to 10.3.

Electrolytic conductivity was measured in order to determine possible soil salinity. The parameter values ranged from 342 $\mu S \cdot cm^{-1}$ to 1544 $\mu S \cdot cm^{-1}$. According to Jakubiak [12], the value of 1000 $\mu S \cdot cm^{-1}$ is considered to be the toleration limit for sensitive plants. There were greater values of this parameter in the samples numbered 2-5, which were collected from the nearest sites to the place of emission, and in sample No. 11 collected from the permanent grassland. Electrolytic conductivity in these samples was greater than 1000 $\mu S \cdot cm^{-1}$, but it did not exceed 2000 $\mu S \cdot cm^{-1}$. This value of electrolytic conductivity shows symptoms of salinity in plants if the soil moisture is good, whereas during a longer dry period it is harmful to plants. Index Z is another parameter indicating the degree of salinity. It refers to the ratio between sodium ions, total magnesium and calcium cations expressed in equivalent amounts. The values of this index in the soil samples ranged from 0.2 to 4.1. Similarly to electrolytic conductivity, there were greater values of this parameter in the samples numbered 2-5, as they ranged from 1.0 to 4.1. In comparison with the data in reference publications [11, 12], in samples No. 2, 3, 5, 7, 11 there was a salinity factor, whereas in samples No. 4 there were conditions for saturation of the sorption complex with sodium cations. The SAR is another important indicator of salinity. The SAR value is determined by calculating the content expressed with equivalent units of sodium, magnesium and calcium ions. The values of this index in the soil samples ranged from 0.2 to 2.7 (Table 1). Although these values were diversified in the samples, there were normal conditions for the growth of plants in the soils under study. Apart from the aforementioned parameters, the soil pH is another important indicator of soil salinity. It enables initial identification of the soil type and distinguishing between salty and sodium soils. The pH limit given in the literature is 8.5 [25]. The pH of the soil samples analysed in this study ranged from 6.25 to 8.16. Among the water-soluble cations under analysis, sodium is the one which considerably influences salinity. Its content was much higher in the samples numbered 2-5 and in sample No. 11 (Table 1).

The research revealed that the degree of salinity did not have statistically significant influence on the count of microorganisms (bacteria, actinobacteria and fungi) or enzymatic activity of soil (dehydrogenases, alkaline phosphatase, urease and protease). Differences in the content of microbial and biochemical indexes depended much more on the type of plants and their specific root secretions, as they influenced a particular population of soil microorganisms stimulating the enzymatic activity of the environment. The differences were also influenced by the content of organic matter and pH of the environment (Table 1). On average, the greatest total count of heterotrophic bacteria was observed in the soil under red clover, whereas the smallest count was found in the soil under seed grass (Table 2). These research results may have been caused by much higher content of total carbon and nitrogen than in the other samples. They may also have been caused by the pH (7.7-8.0) favouring the development of bacteria and by the rich, draining root system of leguminous plants. The concentration of soil microorganisms chiefly depends on the variable chemical composition of root secretions. As results from the reference publications, the species and cultivar of plants growing on the soil surface are decisive to the development and count of microorganisms [35, 40, 41, 42]. The importance of leguminous plants, including clover, results from the fact that they have positive influence on restoring the humus layer and bioactivity in soil [16, 26, 32]. Leguminous plants produce large aerial mass, which is an indispensable source of organic debris for the humus layer and microorganisms in it. The root system, which reaches deep down into the soil, enables the uptake of water and nutrients even under difficult conditions.

As far as actinobacteria are concerned, in the soil under permanent grassland and winter rapeseed the count of these microorganisms was statistically significantly greater than in the soil collected from under the other crops (Table 3). The smallest count of actinobacteria was observed in the soil under seed grass. We can suppose that the highest activity of these microorganisms in the soil under rapeseed was caused by the fact that the actinobacteria used the organic matter which entered the soil with crop residues. Apart from that, the high count of actinobacteria in the soil under permanent grassland and winter rapeseed resulted from the high content of organic matter and the soil pH (7-8), favouring the growth of these microorganisms (Table 1). As results from the statistics, the count of actinobacteria was significantly positively correlated with the content of organic carbon (Table 9). Apart from that, soils under permanent grassland contain more actinobacteria than arable soils. Actinobacteria are capable of synthesising substances with antibiotic properties and they exhibit antibacterial and antifungal effect. By living in symbiosis with plants and fungi they contribute to their better growth, facilitating the uptake of nutrients and affecting plants' defensive mechanisms [33].

Table 1. Basic chemical characteristics of the soils under study
Tabela 1. Podstawo właściwości chemiczne badanych gleb

No.	Crop	C-org	N-tot	C:N	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Z index	SAR index	EC	pH
		%			mg·kg^{-1}						S·cm^{-1}	
1	radish	1.08	0.12	9.2	42.1	10.4	29.6	34.7	0.5	0.4	589	7.83
2	radish	1.60	0.18	9.0	64.2	21.9	62.4	119.6	1.0	1.0	1350	7.87
3	radish	1.12	0.13	8.7	35.9	5.4	28.1	194.8	3.8	2.5	1107	7.98
4	radish	0.92	0.09	10.0	36.7	4.4	65.2	207.2	4.1	2.7	1544	8.05
5	radish	1.03	0.12	8.7	44.7	12.3	31.0	144.5	1.9	1.6	1148	8.03
6	winter rapeseed	0.99	0.11	8.7	36.3	5.8	11.9	48.8	0.9	0.6	530	7.83
7	winter rapeseed	1.10	0.14	8.1	23.6	2.2	27.1	30.1	1.0	0.5	342	7.49
8	winter rye	1.32	0.13	10.2	23.3	2.0	44.9	27.5	0.9	0.5	411	6.25
9	winter rye	1.37	0.13	10.2	66.9	5.3	12.3	26.1	0.3	0.3	561	7.56
10	permanent grassland	2.91	0.29	10.1	106.0	9.0	5.0	54.7	0.4	0.4	852	8.07
11	permanent grassland	5.72	0.52	11.0	65.0	5.8	12.8	115.3	1.3	1.2	1256	8.16
12	red clover	2.62	0.26	10.2	82.6	11.7	19.1	27.8	0.2	0.2	708	8.02
13	red clover	1.27	0.12	10.3	39.8	6.9	30.5	20.8	0.4	0.3	491	7.72
14	seed grass	1.03	0.12	8.7	37.5	9.7	23.0	21.8	0.4	0.3	430	7.83
15	seed grass	0.86	0.09	9.5	29.3	3.6	24.8	21.4	0.5	0.3	378	7.65

Source: own studies / Źródło: badania własne

Table 2. The influence of crops on the total count of heterotrophic bacteria in the soils located in the neighbourhood of emissions from the salt mine

Tabela 2. Wpływ roślin uprawnych na ogólną liczebność heterotroficznych bakterii w glebach położonych w sąsiedztwie emisyjnego oddziaływania kopalni soli

Crop	Mean total count of heterotrophic bacteria [10^5 jtk·g^{-1} d.m. of soil]
seed grass	15.4a
radish	20.8a
winter rye	25.9a
winter rapeseed	34.2a
permanent grassland	36.4a
red clover	69.3b

Source: own studies / Źródło: badania własne

Table 3. The influence of crops on the total count of actinobacteria in the soils located in the neighbourhood of emissions from the salt mine

Tabela 3. Wpływ roślin uprawnych na ogólną liczebność promieniowców w glebach położonych w sąsiedztwie emisyjnego oddziaływania kopalni soli

Crop	Mean total count of actinobacteria [10^4 jtk·g^{-1} d.m. of soil]
seed grass	61.1a
radish	79.3ab
red clover	106.3ab
winter rye	116.3ab
winter rapeseed	131.1bc
permanent grassland	189.2c

Source: own studies / Źródło: badania własne

Table 4. The influence of crops on the total count of moulds in the soils located in the neighbourhood of emissions from the salt mine

Tabela 4. Wpływ roślin uprawnych na ogólną liczebność grzybów pleśniowych w glebach położonych w sąsiedztwie emisyjnego oddziaływania kopalni soli

Crop	Mean total count of moulds [10^4 jtk·g^{-1} d.m. of soil]
red clover	21.2a
permanent grassland	30.9ab
seed grass	41.7ab
radish	44.1ab
winter rapeseed	56.1ab
winter rye	79.0b

Source: own studies / Źródło: badania własne

Table 5. The influence of crops on the dehydrogenase concentration in the soils located in the neighbourhood of emissions from the salt mine

Tabela 5. Wpływ roślin uprawnych na stężenie dehydrogenazy w glebach położonych w sąsiedztwie emisyjnego oddziaływania kopalni soli

Crop	Mean dehydrogenase concentration mmol TPF·kg^{-1}·$24h^{-1}$
winter rapeseed	0.004a
radish	0.005a
seed grass	0.005a
winter rye	0.005a
red clover	0.010b
permanent grassland	0.029c

Source: own studies / Źródło: badania własne

Table 6. The influence of crops on the alkaline phosphatase concentration in the soils located in the neighbourhood of emissions from the salt mine

Tabela 6. Wpływ roślin uprawnych na stężenie fosfatazy zasadowej w glebach położonych w sąsiedztwie emisyjnego oddziaływania kopalni soli

Crop	Mean alkaline phosphatase concentration mmol PNP·kg^{-1}·h^{-1}
seed grass	0.059a
winter rapeseed	0.063a
winter rye	0.067a
radish	0.072a
red clover	0.093b
permanent grassland	0.211c

Source: own studies / Źródło: badania własne

Table 7. The influence of crops on the urease concentration in the soils located in the neighbourhood of emissions from the salt mine

Tabela 7. Wpływ roślin uprawnych na stężenie ureazy w glebach położonych w sąsiedztwie emisyjnego oddziaływania kopalni soli

Crop	Mean urease concentration µmol urea·ml^{-1}·$18h^{-1}$
seed grass	0.205a
winter rye	0.216a
radish	0.245ab
winter rapeseed	0.271ab
red clover	0.301b
permanent grassland	0.387c

Source: own studies / Źródło: badania własne

Table 8. The influence of crops on the protease concentration in the soils located in the neighbourhood of emissions from the salt mine

Tabela 8. Wpływ roślin uprawnych na stężenie proteazy w glebach położonych w sąsiedztwie emisyjnego oddziaływania kopalni soli

Crop	Mean protease concentration mg tyrosine·g^{-1} d.w. soil·h^{-1}
winter rye	0.232a
red clover	0.257a
winter rapeseed	0.258a
radish	0.343a
seed grass	0.368a
permanent grassland	0.569b

Source: own studies / Źródło: badania własne

The greatest count of moulds was observed in the soil under winter rye, whereas the smallest count was found in the soil under red clover. The rye plantation had statistically significant influence on the growth and development of these microorganisms, as compared with the soil samples collected from under the other crops (Table 4). As results from the statistics, the count of fungi was negatively correlated with the soil pH (Table 9). The highest activity of moulds under winter rye was caused by lower values of the soil pH, i.e. 6.26-7.59 (Table 1). Apart from that, the crop residues in the form of organic matter may have been an extra source of nutrients for these microorganisms. Intensive colonisation of rye roots with mycorrhizal fungi in soil is important because they produce glomalins. Their presence in the soil environment plays a significant role in the formation of lumpy soil structure. Apart from that, they are resistant to microbial decomposition, thus being a durable binder of soil particles [24]. Mycorrhizal fungi have positive influence on the growth and development of plants, because they stimulate the uptake of phosphorus and water, protect plants from pathogens, improve the sanitary state and health of plants and stimulate enzymatic activity by aiding plant nutrition [3, 9, 43].

Table 9. Correlation coefficients between selected features
Tabela 9. Współczynniki korelacji pomiędzy wybranymi cechami

Correlation coefficient	Total count of heterotrophic bacteria	Moulds	Actinobacteria	C%	pH	Dehydrogenase	Urease	Alkaline phosphatase	Protease
Total count of heterotrophic bacteria	1.00	0.28	0.46	0.18	- 0.15	0.23	0.19	0.09	0.35
Moulds	-	1.00	0.15	- 0.01	- 0.51	- 0.17	- 0.31	- 0.16	0.23
Actinobacteria	-	-	1.00	0.59	0.20	0.64	0.50	0.63	0.57
C%	-	-	-	1.00	0.30	0.93	0.51	0.93	0.67
pH	-	-	-	-	1.00	0.35	0.52	0.47	0.23
Dehydrogenases	-	-	-	-	-	1.00	0.67	0.96	0.64
Urease	-	-	-	-	-	-	1.00	0.69	0.12
Alkaline phosphatase	-	-	-	-	-	-	-	1.00	0.56
Protease	-	-	-	-	-	-	-	-	1.00

Source: own studies / Źródło: badania własne

As results from the reference publications, vegetation has equally important influence on the activity of soil enzymes [6, 17]. The influence of higher plants on soil enzymes depends on the plant's chemical composition, which may differ between genera, species or even cultivars [7]. Apart from that, the enzymatic activity of soil also depends on its type, abundance of organic and mineral colloids, conditions of vegetation, soil temperature, humidity and pH [3, 6].

The analysis of basic soil enzymes in our study revealed the highest activity of dehydrogenases, alkaline phosphatase, urease and protease in the soil under permanent grassland. The high activity of dehydrogenases, alkaline phosphatase and urease was also observed in the soil under red clover, whereas the high activity of protease was observed in the soil under seed grass. The average values were statistically significantly greater than the concentration of these enzymes in the soil, as compared with the soil samples collected from under the other crops (Tables 5, 6, 7). The high enzymatic activity in the soil under permanent grassland, red clover and seed grass points to the fact that these plants may best stimulate seed transformations of organic compounds of carbon, phosphorous and nitrogen, which are necessary for the growth of higher plants and soil microorganisms. According to Tabatabai [36] and Wielgosz & Szember [40], the activity of soil enzymes may be stimulated by plants' root secretions (glucose, glutamic acid, citric acid, oxalic acid), which activate the development of microorganisms, and by plant debris. According to Farrel et al. [8], Januszek [13], Kieliszewska-Rokicka [17], Kucharski & Wyszkowska [19], microorganisms, underground parts of plants and the soil fauna are the most abundant sources of enzymes. As results from the statistics (Table 9), all of the soil enzymes under analysis (dehydrogenases, alkaline phosphatase, urease and protease) were positively correlated only with the activity of soil actinobacteria. There was not such high correlation observed for the overall activity of heterotrophic bacteria. The research also revealed a negative correlation between the count of moulds and the activity of dehydrogenases, urease and alkaline phosphatase. As results from the reference publications, the activity of dehydrogenases in soil is considered to indicate the intensity of respiratory metabolism of microorganisms, chiefly eubacteria and actinobacteria [3, 25]. Our study showed that dehydrogenase activity was positively correlated with the content of organic carbon and with the total count of heterotrophic bacteria (Table 9). Bielińska [2] also proved in her study that the periods of intensified dehydrogenase activity were accompanied by higher content of C_{org} in soil.

Phosphatase activity reflects the enzymatic activity related with soil colloids and humus substances as well as the activity related with dead or living cells of plants or microorganisms [27, 6, 4]. The correlation coefficients showed a positive correlation between alkaline phosphatase and the content of organic carbon (Table 9). According to Bielińska [1, 2, 3, 5, 17], high activity of these enzymes is correlated with the content of organic carbon and total nitrogen. Herbien & Neal [10] proved that alkaline phosphatase in the soil under barley was positively correlated with the soil pH and content of organic carbon.

Urease can be found in the cells of many higher plants and soil microorganisms (especially bacteria). As results from our study, there was a high positive correlation between urease and the content of organic carbon and soil pH (Table 9). Zhao et al. [46] also observed a significant positive correlation between pH values and the activity of urease, protease and alkaline phosphatase.

Bacteria and, to a lesser extent, fungi are sources of proteases in soil [3]. This fact was confirmed in our study, which showed a positive correlation between the count of actinobacteria and the content of organic carbon (Table 9).

Microbial and biochemical processes in the rhizosphere (the root zone) play an important structural and functional role in the dynamics of plants' nutritional cycle and they can significantly influence the growth and development of plants [3, 22, 28, 31]. Investigations of the enzymatic activity and measurements of the count of microorganisms in the root zone of different plant species and cultivars may be used in practice to indicate the potential of these plants to acquire phosphorus, carbon and nitrogen under different habitat conditions.

4. Conclusions

The following conclusions can be drawn from the research results:

1. The soils in the neighbourhood of the salt mine in Kłodawa were characterised by diversified chemical properties.
2. It was impossible to classify the soils under study as saline soils due to the values of indexes characterising the degree of salinity.
3. There were higher values of electrolytic conductivity, Z and SAR indexes and the content of water-soluble sodium in the samples collected from the direct neighbourhood of the source of emission.
4. The research did not reveal any significant influence of higher, though diversified salinity of soils in the neighbourhood of the salt mine in Kłodawa on the count of basic groups of microorganisms and the enzymatic activity at their accumulation and humus levels.
5. The microbial and biochemical parameters were more influenced by the content of organic matter, pH in the surface soil layers and species of plants grown rather than higher salinity. In most cases the most favourable edaphic conditions for the growth and development of microorganisms were in the epipedons under grassland and plantations of leguminous crops, especially red clover.

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