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INFLUENCE OF POST-SEWAGE WATERS ON RELATIONS BETWEEN EXCHANGEABLE CATIONS IN SOILS

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A b s t r a c t: Research was carried out on the basis of investigations from the years 1996-1998 on the so-called monoliths in the soils derived from loess formations. Properties of those formations were differentiated by landscape and processes of water erosion. It was found out that post-sewage waters (waters received after sewage treatment) from a mechanical-biological sewage treatment plant have a more favourable influence on both the value of acidification indexes and relations between cations in the soils than solid mineral salts.

K e y w o r d s: sewage, eroded soils, cations, relationships.

INTRODUCTION

Municipal wastes, regardless of the degree of treatment they received in mechanical-biological treatment plants, need an additional decrease of the concentration of biogenic components. As the relatively numerous literature on the subject indicates, it can be done in the soil-plant environment [2]. However, the use of sewage on the soil requires not only evaluation of sewage quality but also evaluation of its effect on various soil features, in which a significant position is taken by the physical-chemical properties. These properties are often deformed by the processes of water erosion causing shortage or surplus of particular base cations in the soils formed in various erosion zones [6]. It is a troublesome phenomenon in terms of soil quality, especially when there are too many base cations because, according to Mercik [7], it is relatively hard to get rid of the surplus of base ca-tions. This may cause an improper ion balance in the soil, which negatively influences its yields and chemical composition of plants [9]. There are many papers indicating possibilities of forming such a profitable balance by using mineral salts in the solid form. The influence of post-sewage waters on the relations between cations in the soils with various properties such as reaction and total sorptive capacity is recognized to a lower degree.

The general aim of our studies was a comparative evaluation of the influence of the treated municipal sewage sludge and solid mineral salts on the soil physical-chemical properties, including mainly formation of relations between exchangeable cations.

MATERIALS AND METHODS

The present research was carried out on the basis of investigations from the years 1996-1998 on the so-called monoliths in the soils derived from loess formations differentiated as to their landscape and processes of water erosion. The soils were as follows: W - grey-brown podzolic soil (from the top), N - weakly eroded brown soil (from the northern slope), D - deluvial soil (drifted from the bottom of the valley), and S - strongly eroded calcareous soil (from the southern slope) [2].

Soil samples were collected to plastic containers (called monoliths) and kept for twelve years with undisturbed structure. Then they were placed in the conditions of balanced influence from climatic factors.

Spring rape was cultivated in the monoliths since 1996, together with fodder sunflower, grown as an aftercrop. In 1997 and 1998 common cocksfoot was cultivated there. In one group of the monoliths, plants were supplied with nutrients in the form of post-sewage water, whereas the other group was provided with similar quantities of solid mineral salts.

Post-sewage water was used in the amount of 1 dm^3 per one monolith in each vegetation period for 50 days. Meanwhile, 1 dm^3 of distilled water was used in monoliths, to which mineral salts were added prior to seed sowing, in order to equalise humidity.

Post-sewage waters from the mechanical-biological treatment plant in Lublin contained an average of N - 30, P - 6.4, K - 25, and Mg - 10 mg/dm^3. The following mineral salts were used: ammonium nitrate, triple granulated superphosphate, high percentage potassium salt, and magnesium sulphate.

Soil samples were taken prior to the commencement of investigations with post-sewage water and after plant cropping in the years of 1996, 1997, and 1998. The following parameters were determined in the samples:

- pH in 1 N KCl - using a potentiometer,

- hydrolytic acidity (Hh) - according to the Kappen's method (extraction with the 1 M solution of CH_3COONa/dm^3),
- basic cations (K^+, Na^+, Ca^{2+}, Mg^{2+}) - extraction with the 1 M solution of CH_3COONH_4 with pH 7.0).

Following the results of those denotations, the following values were calculated:

- sum of basic cations (S),
- total sorptive capacity (T),
- quantitative relations between the following cations: S:H and H:Mg; Ca:Mg; K:Mg.

Year	Plant species	Components			
		N	P	K	Mg
1996	Spring rape + Fodder sunflower	1.50	0.32	1.24	0.50
1997	Common cocksfoot	1.50	0.32	1.24	0.50
1998	Common cocksfoot	1.50	0.32	1.24	0.50
Total 1996-1998		4.50	0.96	3.72	1.50

RESULTS AND DISCUSSION

The results of the present investigations indicate that the used post-sewage water differs from the mineral salts applied in a solid shape quite significantly in terms of their effect on pH and hydrolytic acidity of the soil. Under the influence of the above mentioned sewage, regardless of the soil origin, pH increased after the second and the third year of research from the erosion zone, whereas the value of hydrolytic acidity decreased (Table 1). In the objects with mineral salts, pH significantly decreased, while hydrolytic acidity increased. Such a situation must have been the effect of ammonia nitrate. Only in the calcareous soil, pH remained within the range from 7.1 to 7.3. In the same soil, hydrolytic acidity was analogous, i.e.: 4.1 mmol H^+/kg of soil.

It can be expected that the tendency of the pH to grow in the objects with post-sewage water occurred as the result of small amounts of used sewage. It is related to the results of lysimetric research of Janowska [5], which indicated a decrease in the concentration of H^+ ions in the soil that occurred at lower doses of sewage material, while higher doses did not cause any pH changes.

Values of basic cation sums and total sorptive capacity under the influence of both treated municipal wastes and solid mineral salts, were different in various soils and years. However, finally, in most of the cases, the total content of exchangeable cations increased under the influence of the described sewage material

Table 1. pH and hydrolytic acidity (Hh)

Object	Soil	pHKCl				Hh mmol H^+/kg			
		Before experiment 1996	After crop harvesting			Before experiment 1996	After crop harvesting		
			1996 Rape	1997 Orchard grass	1998 Orchard grass		1996 Rape	1997 Orchard grass	1998 Orchard grass
Sewage	W	5.6	5.4	6.7	6.4	24.0	18.2	10.8	12.0
	N	5.1	4.6	5.6	6.3	34.1	29.6	19.8	20.0
	D	6.0	5.9	6.8	5.3	12.1	11.8	9.7	9.4
	S	7.1	6.8	7.5	7.3	4.4	3.4	3.5	3.7
Mineral salts	W	5.6	4.9	4.6	4.5	24.0	18.2	10.8	12.0
	N	5.1	4.3	4.2	4.1	34.1	35.1	43.1	41.6
	D	6.0	5.4	5.0	4.9	12.1	17.6	27.3	25.5
	S	7.1	6.7	6.7	7.2	4.4	3.6	4.5	4.1

Explanataions: W-grey-brown podzolic soil, D-deluvial soil, N-brown soil (weakly eroded), S-calcareous soil (strongly eroded).

in all the soils except calcareous soil. In the soils of the objects with mineral salts, it decreased without any exceptions (Table 2).

An increase in the sum of basic cations in the soils from the three erosion zones, after several years of using treated sewage, may prove an increasing sorptive activity of these soils. According to Janowska [4] and Czyżyk [1], this state can be relevant for Ca, Mg, and K cations because Na is transported faster into the soil profile at sewage application, despite its accumulation in higher amounts.

Table 2. Sum of bases (S) and total cation exchange capacity (T)

Object	Soil	S in mmol (+)/kg				T in mmol (+)/kg			
		Before experiment 1996	After crop harvesting			Before experiment 1996	After crop harvesting		
			1996 Rape	1997 Orchard grass	1998 Orchard grass		1996 Rape	1997 Orchard grass	1998 Orchard grass
Sewage	W	60.9	67.8	61.2	69.5	84.9	86.0	72.0	81.5
	N	62.6	78.8	66.8	83.7	96.7	108.4	86.6	103.7
	D	86.2	87.4	66.7	91.9	98.3	99.2	76.4	101.3
	S	232.6	193.1	195.4	210.6	237.0	196.5	198.9	214.3
Mineral salts	W	60.9	58.8	38.6	40.7	84.9	85.8	73.5	73.3
	N	62.6	73.9	52.9	62.0	96.7	109.0	96.0	103.6
	D	86.2	82.1	54.6	69.3	98.3	99.7	81.9	94.8
	S	232.6	214.5	195.5	211.2	237.0	218.1	200.0	215.3

Explanations as in Table 1.

Generally, it can be stated that the post-sewage water used during three vegetation periods, affected reaction, hydrolytic acidity, sum of basic cations, and total sorptive capacity of the soils more than fertilization with solid mineral salts.

Differences between post-sewage water and mineral salts, in terms of shaping hydrolytic acidity and the sum of basic cations, have also been clearly proved by the calculated ratio of S:H. In the soils with post-sewage water, this ratio increased each year, whereas in objects with mineral salts it decreased. It is clear that regardless of the fertilization shape, the described ratio was the highest in the calcareous soil. After three years, under the influence of sewage, differences between the values of S:H in the calcareous and other soils decreased. In the calcareous soil, however, they were still several or over a dozen times higher than in other soils. In objects with mineral soils, after three vegetation periods, the values of the described ratio were about 20 to over 40 times higher in the calcareous soil than in other soils (Table 3).

Differences in the effect of post-sewage waters and mineral salts were also manifested in terms of the H:Mg ratio in the soils. Sewage in the second and in the third season significantly decreased this ratio, while mineral salts increased it (Table 3).

Table 3. Values of ratios of sum of bases (S) and hydrogen cations (H) and H:Mg

Object	Soil	S:H				H:Mg			
		Before experiment 1996	After crop harvesting			Before experiment 1996	After crop harvesting		
			1996 Rape	1997 Orchard grass	1998 Orchard grass		1996 Rape	1997 Orchard grass	1998 Orchard grass
Sewage	W	2.5	3.7	5.7	5.8	4.8	4.3	1.4	1.7
	N	1.8	2.7	3.4	4.2	7.1	6.0	2.1	2.2
	D	7.1	7.4	6.9	9.8	1.0	2.4	1.0	1.0
	S	52.9	56.8	55.8	56.9	0.7	0.9	0.3	0.3
Mineral salts	W	2.5	2.2	11.1	1.2	4.8	8.4	12.0	10.9
	N	1.8	2.1	1.2	1.5	7.1	7.8	7.8	7.8
	D	7.1	4.7	2.0	2.7	1.0	3.7	4.8	4.4
	S	52.9	59.6	43.4	51.5	0.7	0.9	0.4	0.4

Explanations as in Table 1.

Interesting results were obtained also for the ratios of Ca:Mg and K:Mg. In both cases, after the first year of the experiment with spring rape and sunflower, regardless of the shape of the fertilizer applied in all the soils, the values of these ratios increased, and after three vegetation seasons they significantly decreased (Table 4). In terms of soil fertility, it is especially important to decrease the initial

Table 4. Values of Ca:Mg and K:Mg ratios

Object	Soil	Ca:Mg				K:Mg			
		Before experi-ment 1996	After crop harvesting			Before experi-ment 1996	After crop harvesting		
			1996 Rape	1997 Orchard grass	1998 Orchard grass		1996 Rape	1997 Orchard grass	1998 Orchard grass
Sewage	W	8.2	12.2	5.8	8.0	2.6	2.4	0.8	0.6
	N	10.0	11.7	4.7	7.1	1.7	2.9	1.0	0.6
	D	5.3	13.7	5.2	7.9	0.6	2.3	0.6	0.4
	S	32.2	46.5	13.1	15.7	2.2	2.6	0.4	0.3
Mineral salts	W	8.2	14.1	9.6	11.1	2.6	3.0	2.5	1.3
	N	10.0	12.2	6.5	9.3	1.7	3.0	2.0	1.3
	D	5.3	13.6	7.1	10.0	0.6	2.4	1.4	0.8
	S	32.0	48.3	17.1	20.8	2.2	2.8	0.8	0.6

Explanations as in Table 1.

ratio of Ca:Mg, which is too high in the calcareous soil, from 32 to 16 - in the sewage objects, and to 21 - in mineral salt objects. It is certain that this situation was influenced by the fertilization method and not only by the fact that those soils remained outside the influence of water erosion for many years. That fact, as shown in other papers of Dechnik *et al.* [2] did not matter too much in terms of differentiating the ratio of Ca:Mg between the soils from different erosion zones.

Formation of proper relations between exchangeable cations in the soil is very important. Many authors, including Panak and Wojnowska [9], as well as Filipek and Badora [3], point out the need to form proper relations between cations, because it is an important factor in shaping soil fertility and ion balance in plants.

In our case, all the described relations between cations, regardless of their initial state and the place of soil origin, were better in the objects with post-sewage water application than with solid mineral salts.

CONCLUSIONS

1. Post-sewage waters, unlike mineral salts in solid shape, improve pH values, hydrolytic acidity, basic cation sum, and total sorptive capacity of the investigated soils.

2. Differences in the influence of post-sewage waters and mineral salts occurred also in shaping quantitative relations between cations in the soils. After three vegetation seasons, in the objects with post-sewage water, the values of the ratios of S:H, H:Mg, Ca:Mg, and K:Mg were better in terms of soil fertility.

3. Generally, it can be stated that post-sewage waters from the mechanical-biological treatment plant in Lublin had better influence on the investigated features than mineral salts. Those features are included in the physical-chemical properties of the soils from various erosion zones.

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