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Piotr KACORZYK[1]

EFFECT OF THE WAY OF UTILIZATION AND THE LEVEL OF FERTILIZATION ON THE QUALITY OF LEACHATE WATER PART I. THE CONCENTRATION OF MINERAL COMPONENTS IN LEACHATE WATER

WPŁYW SPOSOBU UŻYTKOWANIA I POZIOMU NAWOŻENIA NA JAKOŚĆ WÓD ODCIEKOWYCH CZ. I. STĘŻENIE SKŁADNIKÓW MINERALNYCH W WODACH ODCIEKOWYCH

Abstract: The investigations were conducted in Czarny Potok on the slope of Jaworzyna Krynicka (650 m above sea level, 20°55′32″ E, 49°24′51″ N). The experimental field was located on the brown, acid soil of the loamy sand granulometric composition, characterized with medium potassium concentration and very poor in phosphorus. Three different parts, as regards plant coverage, were distinguished in the experimental area: the grassland, the arable land and the forest. Analysing the monthly course, higher ammonia and nitrate nitrogen concentration could be noticed during the autumn, when the vegetation process is inhibited and the nitrate uptake less intensive. The phosphorus level in water was very low and ranged from several to a few dozen hundredth part of mg $\cdot$ dm^{-3}. When potassium, calcium and magnesium content in leachate water is taken into consideration it can be stated that it is affected by the amount of rainfall. The calcium and magnesium level in leachate water during the summer months is also influenced by the more intensive nitrification. Hydrogen ions from the sorptive complex displace the calcium and magnesium ions, which are transported with the rain water deep into the soil profile. Leachate waters from the particular variants differed as regards nitrate nitrogen, potassium, calcium and magnesium content. The highest level of these components was observed for leachate water from the arable land and from the forest.

Keywords: fertilization, plant coverage of the soil, water, macroelements

The agricultural and forest management in the mountain area, especially the proportions of certain cultivations in the total area as well as the kind and amount of fertilizers should be performed with respect to their influence on the natural environment. Special attention needs to be paid to the water reservoirs formed in this region, as

[1] Department of Grassland Management, University of Agriculture in Krakow, al. A. Mickiewicza 21, 31–120 Kraków, Poland, phone: +48 12 662 43 60, email: rrkacorz@cyf-kr.edu.pl

they cover above 30 % of the total requirements for water in our country [1]. Inconsiderate agricultural activity can cause many negative changes, eg: soil erosion, anthropogenic eutrophisation, changes in landscape etc. The permanent grasslands, due to yearly plant coverage, protect soil against erosion, have purifying effect as regards water and air and constitute a part of mountain landscape. Hydrological functions of grasslands are especially important in respect of the significance of mountain regions as water resources [2, 3].

The aim of the conducted study was an estimation of the effect of soil plant coverage on the content of mineral compounds in leachate waters.

Materials and methods

The investigations were conducted in Czarny Potok on the slope of Jaworzyna Krynicka (650 m above the sea level, 20°55′32″ E, 49°24′51″ N). The experimental field was located on the brown, acid soil of the loamy sand granulometric composition. The maximum water capacity measured for undisturbed soil amounted to 59 %. The soil was characterized with medium potassium concentration and was very poor in phosphorus. The inclination of the slope, where the investigation was located was 4 % NE. The vegetation period in this region lasts from 150 to 180 days and the duration of snow cover was about 150 days. The rainfalls in 2007 amounted to 504.6 mm – for vegetation period and 930.5 mm – for the whole year and in the year 2008 – 480.3 mm and 781.9 mm, respectively.

Three different parts, as regards plant coverage, were distinguished in the experimental area: the grassland, the arable land and the forest.

The following variants were found on the permanent grassland:

– the meadow which was not fertilized and not mown (non-utilized meadow);

– the fertilized and mown $P_{25}K_{50}N_{120}$ meadow (utilized meadow).

The following crop rotation with $P_{25}K_{50}N_{120}$ fertilization was practiced on the arable land: root crops, cereals, cereals with undercrops and legumes:

– oat was sown in 2007 and potatoes planted in 2008.

Three parts were divided from the forest area:

– beech, spruce and mixed forests.

Not fertilized and not mown meadow is the object where no pratotechnical practices were done. The dominating species of its sward were tufted hairgrass (*Deschampsia caespitosa* L.), red fescue (*Festuca rubra* L.) and lady's mantle (*Alchemilla pastoralis* Bus.). The fertilized and mown meadow was every year fertilized with mineral fertilizers: phosphorus – once in the spring as triple superphosphate 46 %; potassium in the form of potassium salt 56 % in equal doses for the first and second regrowth; nitrogen as ammonium saltpetre 34 % – two doses: for the first regrowth – 60 % of the total nitrogen fertilizer and for the second regrowth – 40 %. Meadow fescue (*Festuca pratensis* Huds.) and kentucky bluegrass (*Poa pratensis* L.) were dominating species in the sward. The first regrowth was collected at the turn of II and III decade of June and the second during the III decade of August. The following doses of pre-sown fertilizers were applied for the arable land in 2007: 25 kg P $\cdot$ ha^{-1} phosphorus as triple superphosphate 46 %; 50 kg K $\cdot$ ha^{-1} as potassium salt 56 % and 120 kg N $\cdot$ ha^{-1} in the form of ammonium saltpetre 34 %. The amount of nitrogen was divided into two doses: one was utilized before sowing and the second as top dressing at the stage of oat tillering. The sowing rate was 160 kg $\cdot$ ha^{-1}. In 2008 on the arable land intended for growing potatoes, cattle-sheep manure in an amount of 20 Mg $\cdot$ ha^{-1} was applied. The concentrations of nutrients in manure used were as follows: total N – 0.69 %; P – 0.14 %; K – 0.60 %; Ca – 0.25 %; Mg – 0.08 %; Na – 0.06 %. The forest experimental field was left without any operations except the measurements of leachate water.

Lysimeters collecting leachate water were installed at the beginning of the spring 2005 in three replicants for each of the above-mentioned experimental variants. Because of the low level of soil thickness lysimeters were installed by digging to a depth of 40 cm and the summary area of each of them was round-shaped of 50 cm diameter (1963 cm^2). The funnel bottoms of lysimeters were filled with gravel, water was removed using a tube to plastic containers located in the cellar. The rainfalls were measured using the Helman rain-gauge and measurements were conducted after each rainfall. In leachate water the content of the following components were evaluated: N-NH_4, N-NO_3 – using LF 205 microprocessor photometer (Slangi); P, K, Ca, Mg and Na – by ICP-AES method using JY 238 Ultrace apparatus. The obtained results were subjected to statistical analysis of one-way variance and LSD test at the significance level of $\alpha < 0.05$, using Statistica 7 software.

The results of investigations and discussion

Table 1 presents the concentrations of the particular mineral components in leachate waters collected in 2007 and 2008. Analysis of the results obtained for the leachate water from the leafy, coniferous and mixed forest area revealed that concentrations of all components were almost equal and the differences were not statistically significant. For these three variants the arithmetic mean was calculated and presented as “forest”.

On the meadow, the average ammonium nitrogen (N-NH_4) content for the vegetation period in water flowing through the soil profile was similar and the lowest on the level of 0.10–0.11 mg $\cdot$ dm^{-3}. The arable land and forest were characterized by a significantly higher N-NH_4 content (by above 50 %). High concentration of ammonium nitrogen in leachates observed during different seasons of the year for all variants can result from the high level of rainfalls and in consequence faster infiltration into the ground, limiting the proceeding of biochemical transformations of ammonium ions. However, the concentration of this component was close to that reported in literature [4–6].

The content of nitrate nitrogen (N-NO_3) in leachate water for both meadow objects was usually at the level of tenth parts of mg $\cdot$ dm^{-3}, less frequently it reached the level of few mg $\cdot$ dm^{-3}. Distinctly higher concentration (7–9 times higher) was observed for leachates from the arable land, and a dozen times higher for the forest area. Large variability of the concentration during the whole plant vegetation period can be noticed. The lowest values were characteristic for spring and winter months, whereas the highest were stated in summer and autumn. The low level of N-NO_3 in leachate water in spring resulted from intensive plant development and utilization of nitrate nitrogen for biomass

Table 1

The concentration of mineral components in leachate water [mg · dm^{-3}]

Variant	Year/Season	[mg · dm^{-3}]													
		$N\text{-}NH_4$		$N\text{-}NO_3$		P		K		Ca		Mg		Na	
	Year	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Non-utilized meadow	Spring	0.20	0.10	0.63	0.47	0.21	0.03	1.25	0.32	11.58	43.2	1.50	1.61	0.58	0.71
	Summer	0.20	0.12	1.63	1.24	0.13	0.03	1.08	0.62	19.37	68.8	1.98	2.45	0.93	1.05
	Autumn	0.08	0.06	0.61	0.14	0.28	0.02	1.09	0.25	61.59	69.2	3.03	1.58	1.14	0.74
	Winter	0.00	0.00	0.47	0.18	0.02	0.02	0.35	0.19	8.96	42.8	1.6	1.64	0.80	0.71
	Average	0.10^{a}		0.67^{a}		0.09^{b}		0.64^{a}		40.69^{bc}		1.92^{a}		0.83^{a}	
Fertilized meadow	Spring	0.12	0.10	0.41	0.88	0.43	0.05	2.39	0.18	9.65	9.28	1.05	1.09	0.67	0.67
	Summer	0.16	0.10	1.35	1.35	0.06	0.03	0.75	0.24	11.25	9.44	1.27	1.29	1.13	0.66
	Autumn	0.16	0.20	0.77	2.10	0.12	0.02	0.55	0.19	10.92	9.56	1.18	1.6	0.93	0.89
	Winter	0.00	0.08	1.11	0.43	0.04	0.02	0.56	0.53	7.88	8.32	1.04	1.09	0.72	0.57
	Average	0.11^{a}		1.05^{b}		0.10^{b}		0.67^{a}		9.54^{a}		1.20^{a}		0.78^{a}	
Arable land	Spring	0.28	0.29	2.26	0.88	0.16	0.03	1.04	0.54	24.87	16.76	2.34	2.08	0.81	0.97
	Summer	0.23	0.15	10.39	6.10	0.10	0.06	2.02	0.79	63.88	19.44	6.55	3.40	2.92	2.48
	Autumn	0.16	0.24	7.68	18.08	0.08	0.03	1.37	1.48	61.14	23.32	6.15	7.45	2.64	7.67
	Winter	0.00	0.00	4.75	0.68	0.03	0.02	0.96	0.42	33.52	10.40	2.94	2.34	1.90	1.02
	Average	0.17^{ab}		6.35^{c}		0.06^{a}		1.08^{b}		31.67^{b}		4.16^{b}		2.55^{c}	
Forest	Spring	0.18	0.14	10.85	8.81	0.09	0.03	3.95	3.32	38.52	31.32	3.68	2.95	1.99	1.28
	Summer	0.16	0.17	17.17	10.62	0.07	0.04	5.19	3.88	49.18	36.96	4.32	2.62	2.13	1.44
	Autumn	0.39	0.19	18.30	19.66	0.09	0.02	3.58	2.50	83.41	29.00	7.46	1.96	3.31	1.00
	Winter	0.00	0.03	3.62	6.33	0.06	0.03	2.75	2.68	41.00	27.36	3.03	3.28	1.98	1.56
	Average	0.16^{ab}		11.92^{d}		0.05^{a}		3.48^{c}		42.09^{bc}		3.66^{b}		1.84^{b}	

* Homogeneous groups according to LSD test, $\alpha < 0.05$, s.i. – statistically insignificant.

production. During the summer and autumn period the vegetation process proceeds slower than during the spring and in the autumn it is stopped, which results in less intensive uptake of this form of nitrogen. Additionally during the summer period the nitrification process is more intensive. During the autumn of 2007, concentration of $N-NO_3$ in leachate water from the arable land was stated to be 57 % lower than in the respective period of the following year. It was probably due to high C:N rate in post-harvest remains (oat straw), microorganisms which hydrolyze organic matter used up nitrogen, whereas in the winter higher level of $N-NO_3$ in leachate water from that object was observed because of microorganism decomposition.

The content of phosphorus in water was very low and ranged from several to a dozen parts of mg $\cdot$ dm^{-3}. Its average content for the meadow objects amounted to 0.1 mg $\cdot$ dm^{-3}, whereas for leachates from the arable land and forest it was 50 % lower. It results from the very low soil pH level (forest – pH_{KCl} 2.95). Such low pH causes the withdrawal of phosphorus compounds (chemical sorption), the P concentration in soil is also very low. During the experiment there was stated no effect of fertilization or kind of plant coverage on the increase of the phosphate level in leachate water, which is consistent with the results obtained by Czerwinski and Pracz [7].

The lowest concentration of potassium was stated for the water derived from the meadow objects, whereas water from the arable land was characterized by almost twice higher K content. The level of potassium in water from the forest amounted to 3.46 mg $\cdot$ dm^{-3} and was almost 6 times higher than the lowest stated value. When estimating the potassium level it can be found that it is affected by the amount of rainfall, because higher soil moisture favours the replacement and washing out of potassium ions [6]. Another factor influencing the level of this parameter is the level of potassium assimilation by plants.

Among all analysed components, calcium was present in the highest amounts. Similar results were obtained by Szymanska [8]. The lowest Ca level was observed in water from the utilized meadow – 9.54 mg $\cdot$ dm^{-3}. Water from the arable land contained 31.67 mg $\cdot$ dm^{-3} of this element. Ca concentration in leachates from the non-utilized meadow and the forest was above 4 times higher. Generally, the lowest concentration of calcium was observed in the spring and winter period.

The mean Mg content in water was 10–20 times lower when compared with the Ca content, but the major relationships between variants and seasons of the year were very similar. The level of Ca and Mg in leachate water was affected by the total amount of rainfall. Litynski and Jurkowska [9] in their study proved that rainfall is responsible for the greatest losses of these components in soil, because they are removed and washed out. The nitrification, more intensive during the summer period, also affects the washing out. Hydrogen ions displace calcium and magnesium ions from the sorptive complex and transport them with rain water deep into the soil profile.

The average sodium content in leachate water was below 1 mg $\cdot$ dm^{-3} for both meadows and above 2.5 mg $\cdot$ dm^{-3} for the arable land. Water obtained from the forest contained a twice higher level of this element when compared with the meadow variants. The highest concentration of sodium in leachate water (7.67 mg $\cdot$ dm^{-3}) was observed in the autumn 2008 in the arable land. This large amount of Na resulted from decomposition of cattle-sheep manure, which is rich in this element (0.06 mg · kg). Manure was applied on this object at the end of April and during the spring and summer it was assimilated by potatoes.

The high level of minerals in leachate water for the forest object is elaborated in the second part of the present work entitled "The loads of components in leachate water".

Conclusions

1. Intensive rainfall is the major factor influencing higher concentration of N-NH_3 in leachate water.
2. N-NO_3 content in leachate water is affected by the soil plant coverage as well as intensity of plant development.
3. The low phosphorus content and low pH of the soil determined the low level of this element in water.
4. Potassium, calcium and magnesium concentration in leachates was affected by the plant coverage of the soil as well as intensity of rainfall.
5. Sodium content in water is influenced by its content in the soil.

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WPŁYW SPOSOBU UŻYTKOWANIA I POZIOMU NAWOŻENIA NA JAKOŚĆ WÓD ODCIEKOWYCH CZ. I. STĘŻENIE SKŁADNIKÓW MINERALNYCH W WODACH ODCIEKOWYCH

Katedra Łąkarstwa
Uniwersytet Rolniczy im. Hugona Kołłątaja w Krakowie

Abstrakt: Badania prowadzono w Czarnym Potoku u podnóża Jaworzyny Krynickiej (650 m n.p.m., 20°55′34″ E, 49°24′35″ N). Na polu doświadczalnym występowała gleba brunatna o składzie granulometrycznym piasku gliniastego. Była to gleba kwaśna, średnio zasobna w potas, a bardzo uboga w fosfor. Na terenie doświadczalnym wydzielono trzy części (różniące się okrywą roślinną gleby): użytek zielony, grunt orny i las. Analizując przebieg miesięczny, można zauważyć większe stężenie azotu amonowego i azotanowego w miesiącach jesiennych, kiedy to proces wegetacji zostaje zahamowany, więc i pobieranie azotanów jest mało intensywne. Zawartość fosforu w wodzie była bardzo niska i kształtowała się na poziomie kilku lub kilkunastu setnych części mg $\cdot$ dm^{-3}. Oceniając stężenie potasu, wapnia i magnezu w wodzie odciekowej można stwierdzić, iż zależy ono od ilości opadów atmosferycznych. Na zawartość wapnia i magnezu w wodzie odciekowej w miesiącach letnich ma wpływ również nitryfikacja nasilona w tym okresie. Jony wodorowe wypierają z kompleksu sorpcyjnego jony wapnia i magnezu i przemieszczają je z wodami opadowymi w głąb profilu glebowego. Wody odciekowe z poszczególnych wariantów znacznie się różniły pod względem zwartości azotu azotanowego, potasu wapnia i magnezu. Najwięcej tych składników zawierały wody odciekowe z gruntu ornego i lasu.

Słowa kluczowe: nawożenie, okrywa roślinna gleby, woda, makroskładniki