Pedological aspects in the functioning of spring niches as transition zones between underground and superficial parts of the water cycle in a river basin

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Abstract. The aim of the study was to characterize the soils of spring niches in the valley of the Jarosławianka River in the context of its functioning in the transition zone between underground and superficial parts of the water cycle in the river basin. Five spring niches, representing different soil types (proper gley soils, peat-like soils, peat-mud soils) were studied. Small-scale relief in nearby water seepages is an important factor, which determined the direction of pedogenesis in spring niches. The relief can enhance or hinder accumulation of organic matter. Specific characteristics of soil-forming environment of spring niches (water surplus and its permanent flow through the soil) are reflected in some chemical properties of the soils (low concentration of active and plant-available forms of N, P and K) and properties of soil organic matter (a low rate of the humification process). Soil organic matter strongly affects the sorption and buffer properties of the soils. Ionic composition of the soil sorption complex is determined by the chemistry of feeding waters. More than 99.3% of total cations are bases, especially calcium.

Key words: hydrogenic soils, water cycling, soil properties, soil organic matter.

1. Introduction

Spring niches are transition zones between underground and superficial parts of water cycle in river basin (Jekatierynczuk-Rudczyk 2005; Mazurek 2006). Water plays important role in functioning of spring niches. Quantity and quality of supplying water effects plant communities (Osadowski 2006; Wołejko 1996) and the direction of pedogenesis. The surplus of water makes conditions for development of hydrogenic soils. Properties of the soils reference to the character of past and present plant communities, as well as chemistry of supplying waters. Soil, as basic structural and functional component of the ecosystems of spring niches, influenced on the properties of lotic water. Transformation of the chemistry of water can be deep even in small spring niches (Jekatierynczuk-Rudczyk 2005, 2006, 2007). The complex of physical and chemi-

cal properties of the soils, as well as the intensity of biochemical processes (connected with functioning of plant communities and soil microflora and fauna), determined direction and range of the transformation. Soil physical, chemical, sorption and buffer properties, which are determined by the amount and quality of soil organic matter play an important role.

The aim of the study was to characterize physical, chemical, sorption and buffer properties as well as some properties of organic matter of the soils of spring niches in the valley of the Jarosławianka River in the context of its functioning in the transition zone between underground and superficial parts of the water cycle in the river basin.

2. Materials and methods

Jarosławianka is a small river located in the area of a late-glacial depression of the Sławieńska Plain. The river basin has a character of a spring basin, 5.74 km^2 in area. Superficial deposits are very acid and low permeable hollow clays and silts or kame deposits, flat-dipping on very compact, calcareous glacial tills. Between hollow or kame deposits and glacial tills, sandy interbeddings occur, which are water-bearing layers. The lower part of the Jarosławianka River is incised in superficial deposits more than 10 m. The incision, which is the effct of rapid water runoff from a postglacial lake, exposed the water-bearing layer. Recently, numerous water seepages are active along the slopes of the river valley. In the vicinity of some water seepage areas, the ground becomes boggy and spring niches develop.

The studies were conducted in five spring niches in the lower part of the Jarosławianka River. One soil profile was made in the central part of each spring niche. The soils were described according to the Taxonomy of Polish Soils (1989). Two volume samples using 100 cm^3 rings and one sample as a monolith were taken from each soil horizon. The following parameters were analyzed in the samples:
- bulk density using 100 cm^3 steel rings;
- specific density by the burette method;
- total porosity –calculated on the basis of bulk density and specific density;
- specific surface area by the method of adsorption of glycerin vapors;
- grain size distribution by the mixed pipette and sieve method;
- soil organic matter (SOM) content as a weight loss on ignition in 550°C;
- reaction in H$_2$O and 1mol·dm^{-3} solution of KCl;
- the content of total organic carbon (TOC) by Alten's method;
- the content of total organic nitrogen (TON) by Kjeldahl's method;
- the content of easily hydrolyzing nitrogen (N$_h$) in solution of 0.25M H$_2$SO$_4$;
- the content of water-extractable (active) forms of nitrogen, phosphorus and potassium after shaking the soil and water in the weight proportion of 1:10 for 1 hour. The following was analyzed in the solution: the total amount of dissolved organic nitrogen and ammonium nitrogen (DON) by Kjeldahl's method, nitrate nitrogen (N-NO$_3$) with sodium salicylate, phosphate (P$_a$) by the molybdenum blue method, potassium (K$_a$) by flame emission spectrometry;
- the content of total phosphorus (P$_t$) and potassium (K$_t$) in the solution after digestion in a mixture of 40% HF and 60% HClO$_4$ in the volumetric proportion of 3:1.

The concentration of elements was determined by the aforementioned methods;
- the content of plant-available forms of phosphorus (P$_{pa}$) and potassium (K$_{pa}$) by Egner-Riehm method;
- the content of exchangeable bases [Ca^{2+}, Mg^{2+}, K$^+$, Na$^+$] in 1 mol·dm^{-3} and pH = 7.0 solution of CH$_3$COONH$_4$. Concentration of Ca, K and Na was analyzed by flame emission spectrometry, Mg by the versenate method;
- exchangeable acidity [H$_w$ and Al$_w$] by Sokolov's method;
- buffer properties by Arrhenius' method;
- fractional composition of humus by the method of Kononova and Belčikova (Dziadowiec & Gonet 1999). The following parameters were determined in the humus: the content of carbon in easily soluble organic components (fraction C3), humic acids (CKH1, CKH2), fulvic acids (CKF1), residue after extraction (CPP). The humification rate was calculated as: ((CKH1+CKF1)*100)/TOC;
- absorbance values of 0.01% alkaline solutions of humic acids at a wavelength of 465 and 665nm. E$_{4/6}$ ratio was calculated as absorbance 465 nm/absorbance 665 nm.

3. Results and discussion

Proper gley soils, peat-like soils and peat-mud soils are typical for spring niches in the valley of the Jarosławianka River. A different direction of the soil development in such spring niches was determined by different locations of water seepages on the valley slopes and small-scale relief in the proximity of seepages. Proper gley soils develop in the proximity of seepages in upper parts of the slopes. A hillside slope reduces the process of bogging, and the surplus of water leads only to deep gleying of the soil profile. The general structure of the soils is Agg-G. In small depressions of the lower parts of slopes, peat-like soils occur with the horizon system of Ae-Agg-G. Low thickness of the profile, deep gleying and high concentration of organic matter are characteristic features of the soils. At the foot of slopes, in larger depressions, peat-mud soils develop. The soils are built of silting up organic horizons, sometimes interbedded by mineral or organic-mineral alluvium.

SOM content is a basic feature differentiating the soils of spring niches. The lowest content of SOM was noticed in the profile of proper gley soils (5.0%), higher content in peat-like soils (up to 8.8%), and the highest one in peat-mud soils – up to 51.0% (Table 1). SOM is slightly humified – the humification rate from 9.8 to 37.3% (Table 2). The majority of humic acids in relation to fulvic acids is a favorable feature. High values of the absorbance ratio E$_{4/6}$ confirmed low aromaticity of humic acids. The observed properties of SOM can result from limitation of the humification process in conditions of water surplus. Very low

Table 1.　Selected chemical properties of the soils

Horizon	Depth [cm]	pH in H_2O	pH in 1M KCl	$CaCO_3$ [%]	Loss on ignition [%]	TOC [$g \cdot kg^{-1}$]	TOC/ TON
niche nr 1 – proper gley soil							
Agg	0–20	7.0	6.4	0.0	5.0	24.4	19
G1	20–44	7.5	6.6	<0.1	3.3	–	–
G2	44–62	7.7	6.7	<0.1	3.1	–	–
G3	62–110	7.4	6.3	0.0	1.1	–	–
niche nr 2 – peat-mud soil							
POtmn	0–15	6.6	6.2	0.0	50.6	267	15
O1tmn	15–42	6.4	6.0	0.0	34.1	182	15
O2tmn	42–70	6.8	6.0	0.0	36.5	199	17
n	70–90	7.1	6.1	0.0	16.0	84.0	20
O3mn	90–110	6.9	6.1	0.0	23.2	127	16
D	110–150	-	-	0.0	1.4	–	–
niche nr 3 – peat-like soil							
Ae	0–24	6.5	6.0	0.0	8.6	43.2	20
Agg	24–54	6.7	6.5	0.0	8.8	46.2	24
G	54–80	6.7	6.3	<0.1	1.7	–	–
niche nr 4 – peat-mud soil							
POtmn	0–34	6.1	5.4	0.0	30.9	197	32
Otmn	34–70	6.6	5.9	0.0	25.6	128	18
n	70–82	6.6	5.5	0.0	10.4	45.7	16
D	82–110	7.5	6.4	<0.1	1.7	–	–
niche nr 5 – peat-mud soil							
POtmn	0–22	6.7	6.2	0.0	26.4	138	14
Otmn	22–47	6.5	6.1	0.0	51.0	271	16
D	47–80	7.0	6.2	<0.1	1.7	–	–

– not analyzed.

concentration of CKF1a fraction can indicate high intensity of leaching of dissolved organic matter (Table 2).

SOM influences the physical and chemical properties of the soils of spring niches. An increase of SOM content leads to a decrease of bulk density and specific density, as well as an increase of total porosity and specific surface area (Table 3). Maximum values of bulk density were noticed in the mineral bed of organic soils and minimum values in organic horizons of peat-mud soils. Total porosity ranged from 38.4 to 89.2%. The lowest porosity was

observed in the profile of proper gley soils, higher porosity − in peat-like soils and the highest one in organic horizons of peat-mud soils (Table 3). Similar trends are observed for specific surface area, which was 8.6–22.6 $m^2 \cdot g^{-1}$ for proper gley soils, 14.5–26.4 $m^2 \cdot g^{-1}$ for peat-like soils and 36.4–46.5 $m^2 \cdot g^{-1}$ for peat-mud soils. The observed values are not high. This can result from low content of the clay fraction and low degree of SOM humification.

The feeding water significantly affects the soil reaction in spring niches. pH of the soils in the analyzed profiles

Table 2. Fractional composition of soil organic matter (explanation of symbols in the text)

Horizon	CKF1a [0.05M H_2SO_4]	0.1M $Na_4P_2O_7$ + 0.1M NaOH						CKH2 [0.1M NaOH]	CKHCa [CKH1-CKH2]	CPP
		CKH1	CKF1	CKH+CKF1	CKH:CKF	Humification rate	$E_{4/6}$			
	%	%				%		%		
niche nr 1 – proper gley soil										
Agg	0.06	0.26	0.15	0.42	1.73	17.0	7.82	0.15	0.12	2.02
niche nr 2 – peat-mud soil										
POtmn	0.32	1.99	1.37	3.35	1.45	12.6	5.69	1.14	0.85	23.3
O1tmn	0.18	1.90	0.85	2.75	2.24	15.1	5.85	1.31	0.59	15.4
O2tmn	0.18	2.01	0.86	2.87	2.35	14.4	5.56	0.98	1.04	17.0
n	0.10	1.50	0.59	2.09	2.56	24.9	4.73	0.58	0.92	6.31
O3mn	0.10	1.01	2.32	3.33	0.44	26.2	5.64	0.61	0.40	9.40
niche nr 3 – peat-like soil										
Ae	0.14	0.44	0.32	0.76	1.39	17.7	7.00	0.36	0.09	3.56
Agg	0.10	0.44	0.30	0.74	1.45	15.9	6.07	0.33	0.10	3.89
niche nr 4 – peat-mud soil										
POtmn	0.24	1.91	1.14	3.05	1.68	15.5	6.27	1.41	0.51	16.7
Otmn	0.21	0.94	0.47	1.41	1.99	11.0	5.12	0.88	0.05	11.4
n	0.18	1.37	0.34	1.70	4.09	37.3	4.22	0.62	0.75	2.87
niche nr 5 – peat-mud soil										
POtmn	0.31	2.48	1.07	3.55	2.33	25.7	6.16	1.48	1.00	10.3
Otmn	0.26	1.80	0.86	2.66	2.09	9.8	5.85	0.74	1.06	24.4

ranged from 6.1 to 7.7 (Table 1). The content of carbonates was very low. The lack of accumulation of carbonates probably results from the presence of very acid, calcium-poor deposits on the water-bearing layer.

Soils of spring niches were in general rich in all forms of nitrogen (Table 4). Concentration of TON was the lowest in proper gley soils (0.34–1.29 g·kg^{-1}), higher in peat-like soils (1.93–2.11 g·kg^{-1}) and the highest in organic horizons of peat-mud soils (4.38–17.45 g·kg^{-1}) (Table 4). TOC:TON ratio ranged from 14:1 to 32:1. In general, lower values of the ratio were observed in superficial horizons in relation to subsurface horizons (Table 1).

The concentration of the easily-hydrolyzing form of nitrogen was 30.8–500.3 mg·kg^{-1} of soil (1.3–5.0% in relation to TON) (Table 4). Kalembasa and Becher (2009) recorded the concentration of N_h in the range of 441–609 mg·kg^{-1} and the contribution of the aforementioned form between 20.7 and 24.9% of TON. The concentration of water-extractable forms of nitrogen was also low, especially the nitrate form (N-NO$_3$). Low concentration of N-NO$_3$ in soils of spring niches can from the limited nitrification process due to water surplus (Jekatierynczuk-Rudczyk 2006), as well as intensive denitrification, which is typical for bogged soils rich in organic matter (Davidson & Ståhl 2000). Nitrates are intensively uptaken during vegetation season, which leads to reduction of N-NO$_3$ in soil solution. Samples of soils were taken in spring, when the concentration of nitrates is usually low compared to summer or autumn (Smólczyński & Orzechowski 2009).

Soils of spring niches were rich in total phosphorus. The concentration of P_t was 0.30–0.45 g·kg^{-1} in proper gley soils, 0.37–0.50 g·kg^{-1} in peat-like soils and 0.63–2.18 g·kg^{-1} in organic horizons of peat-mud soils (Table 4). The contribution of water-extractable and plant-available forms of phosphorus was generally low. The highest concentrations of P_{pa} were in superficial horizons (compared

Table 3. Physical properties of the soils

Horizon	Depth [cm]	Textural group of mineral part	Clay content [%]	Bulk density [g·cm⁻³]	Total porosity [%]	Specific surface area [m²·g⁻¹]
niche nr 1 – proper gley soil						
Agg	0–20	Loamy sand	4.1	1.03	60.2	22.6
G1	20–44	Sandy loam	6.4	1.25	51.4	19.8
G2	44–62	Loamy sand	6.3	1.20	54.4	15.6
G3	62–110	Sand	2.0	1.48	44.6	8.6
niche nr 2 – peat-mud soil						
POtmn	0–15	–	–	0.20	89.1	–
O1tmn	15–42	–	–	0.23	89.2	40.1
O2tmn	42–70	–	–	0.27	86.3	33.8
n	70–90	Sandy loam	8.9	0.56	72.9	38.1
O3mn	90–110	–	–	0.23	89.8	40.6
D	110–150	Sandy loam	12.3	1.60	39.2	19.1
niche nr 3 – peat-like soil						
Ae	0–24	Loamy sand	3.1	0.76	69.6	26.4
Agg	24–54	Loamy sand	0.0	0.68	72.1	23.5
G	54–80	Sandy loam	6.6	1.60	39.2	14.5
niche nr 4 – peat-mud soil						
POtmn	0–34	–	–	0.32	84.5	45.3
Otmn	34–70	–	–	0.46	79.6	36.4
n	70–82	Sandy loam	6.4	0.80	66.7	40.6
D	82–110	Sandy loam	12.3	1.62	38.4	19.1
niche nr 5 – peat-mud soil						
POtmn	0–22	–	–	0.33	84.6	38.1
Otmn	22–47	–	–	0.24	87.6	46.5
D	47–80	Sandy loam	8.3	1.23	52.3	18.3

– not analyzed.

to subsurface horizons) of soils. The contribution of P_{pa} in relation to P_t was 2.1–6.4% in gley soils, 3.2–4.4% in bogged horizons of peat-mud soils and 0.6–1.9% in subsurface organic horizons of these soils. The contribution of the water-extractable form of phosphorus was 0.2–1.1% (Table 4). Leaching is probably the main cause of low P_a concentration, but some phosphorus can also be immobilized by iron (Sharpley 1995).

The concentration of total potassium was 9.43–15.20 g·kg⁻¹ in proper gley soils, 12.44–13.73 g·kg⁻¹ in peat-like soils, 13.13–18.02 g·kg⁻¹ in the mineral bed of peat-mud soils and 5.91–10.96 g·kg⁻¹ in organic horizons of these soils (Table 4). The contribution of plant-available forms of potassium was 0.3–0.9% in relation to K_t. High mobility of potassium in the environment is probable reason of the observed low concentration of K_{pa} and K_a in soils of spring niches.

Table 4. Concentration of different forms of nitrogen, phosphorus and potassium

Horizon	Nitrogen				Phosphorus			Potassium		
	TON [g·kg⁻¹]	N_h [mg·kg⁻¹]	DON [mg·kg⁻¹]	N-NO₃ [mg·kg⁻¹]	P_t [g·kg⁻¹]	P_{pa} [mg·kg⁻¹]	P_a [mg·kg⁻¹]	K_t [g·kg⁻¹]	K_{pa} [mg·kg⁻¹]	K_a [mg·kg⁻¹]
niche nr 1 – proper gley soil										
Agg	1.29	59.2	70.6	5.0	0.38	17.6	2.4	13.1	37.9	18.6
G1	0.96	48.2	65.8	5.0	0.45	16.9	2.9	15.2	49.0	25.3
G2	0.97	30.8	72.2	4.6	0.30	11.2	2.5	12.0	35.7	18.2
G3	1.29	–	38.1	4.8	0.33	21.0	2.5	9.43	25.7	17.6
niche nr 2 – peat-mud soil										
POtmn	1.45	500	351	17.6	2.18	69.0	19.5	8.01	155	111
O1tmn	11.94	223	99.4	7.0	1.55	19.6	7.2	11.0	75.2	31.5
O2tmn	11.87	170	112	7.0	1.91	15.5	5.8	9.54	51.6	23.2
N	4.28	96.9	78.7	7.2	1.69	15.2	4.0	16.1	93.2	25.6
O3mn	7.72	97.2	58.5	14.0	0.99	5.5	2.9	7.35	40.2	17.6
D		–	–	–	0.37	–	–	13.1	–	–
niche nr 3 – peat-like soil										
Ae	2.11	90.3	94.6	5.2	0.40	23.5	2.9	12.4	30.2	15.8
Agg	1.93	65.7	52.1	3.1	0.50	10.6	1.3	13.7	38.5	16.0
G	0.27	–	–	–	0.37	–	–	13.1	40.6	–
niche nr 4 – peat-mud soil										
POtmn	6.10	241	146	7.9	0.63	27.5	5.8	9.47	87.4	37.6
Otmn	7.03	164	129	6.0	0.76	12.9	2.5	10.8	35.0	11.2
N	2.87	128	112	5.4	0.58	21.6	3.0	13.3	44.5	14.2
D	0.33	–	–	–	0.40	–	–	18.0	55.1	–
niche nr 5 – peat-mud soil										
POtmn	9.65	236	216	8.5	0.71	24.8	6.1	9.48	27.4	14.1
Otmn	17.02	226	318	9.1	0.70	13.2	7.8	5.91	21.3	20.6
D	0.42	–	–	–	0.20	–	–	15.7	42.9	–

– not analyzed.

Large variability of CEC was observed in the studied profiles. Poor in SOM and clay Proper gley soils, poor in SOM and clay, have small sorption capacity CEC 5.20–12.14 cmol$_c$·kg⁻¹. Much higher values of CEC were observed in organic horizons of peat-mud soils – up to 132.83 cmol$_c$·kg⁻¹. Bases dominated in the soil sorption complex (over 99.3%), especially calcium bases (Table 5). High saturation of the soil sorption complex with calcium results from the influence exerted by the feeding water, where calcium is the basic component (Jonczak 2010). High saturation of the soil sorption complex with calcium is typical of the soils with neutral or alkaline pH (Laskowski & Tołoczko 2001; Jaworska et al. 2008).

Different buffer properties were observed in particular profiles of the soils (Fig. 1). Proper gley soils had the lowest buffer capacity. The highest buffer capacity was noticed for peat-like and peat-mud soils. Basic buffer in soils of spring niches in the valley of the Jarosławianka

Table 5. Concentration of exchangeable cations, total of exchangeable bases (TEB), cation exchange capacity (CEC) and base saturation (BS)

Horizon	Depth [cm]	Exchangeable cations [$cmol_c \cdot kg^{-1}$]						TEB [$cmol_c \cdot kg^{-1}$]	CEC [$cmol_c \cdot kg^{-1}$]	BS [%]
		Ca^{2+}	Mg^{2+}	Na^+	K^+	H^+	Al^{3+}			
niche nr 1 – proper gley soil										
Agg	0–20	10.9	0.90	0.20	0.12	0.03	0.005	12.1	12.1	99.8
G1	20–44	11.2	0.93	0.27	0.19	0.02	0.005	12.6	12.6	99.9
G2	44–62	8.51	0.81	0.13	0.10	0.01	0.002	9.55	9.56	99.9
G3	62–110	3.58	1.42	0.12	0.07	0.01	0.003	5.19	5.20	99.7
niche nr 2 – peat-mud soil										
POtmn	0–15	130	0.68	0.85	0.87	0.35	0.05	132	132	99.7
O1tmn	15–42	61.0	4.47	0.38	0.26	0.26	0.05	66.1	66.4	99.6
O2tmn	42–70	53.2	1.62	0.32	0.17	0.22	0.05	55.4	55.6	99.6
n	70–90	27.5	1.22	0.23	0.30	0.04	0.004	29.2	29.3	99.9
O3mn	90–110	49.3	2.84	0.34	0.12	0.11	0.01	52.6	52.7	99.8
D	110–150	-	-	-	-	-	-	-	-	-
niche nr 3 – peat-like soil										
Ae	0–24	17.7	1.22	0.19	0.10	0.02	0.003	19.2	19.2	99.9
Agg	24–54	21.9	1.02	0.22	0.12	0.04	0.005	23.2	23.3	99.8
G	54–80	6.90	0.81	0.11	0.13	0.02	0.007	7.96	7.98	99.7
niche nr 4 – peat-mud soil										
POtmn	0–34	42.3	8.93	0.39	0.28	0.35	0.05	51.9	52.2	99.3
Otmn	34–70	49.8	3.45	0.38	0.14	0.22	0.02	53.7	54.0	99.6
n	70–82	35.2	2.44	0.23	0.17	0.03	0.001	38.0	38.0	99.9
D	82–110	8.20	0.41	0.28	0.22	0.01	0.001	9.11	9.12	99.9
niche nr 5 – peat-mud soil										
POtmn	0–22	67.5	4.06	0.57	0.13	0.22	0.02	72.2	72.4	99.7
Otmn	22–47	89.3	3.65	0.61	0.10	0.22	0.05	93.6	93.8	99.8
D	47–80	7.37	0.81	0.15	0.15	0.02	0.003	8.48	8.50	99.8

– not analyzed.

River is ion-exchange buffer and SOM. Carbonate buffer do not play an important role because of very low concentration of carbonates. An increase of soil buffer capacity was observed along with an increase in the SOM content and CEC. Ion-exchange buffer can be effective in acids neutralization in soils of high CEC. The studies of Malczyk et al. (2008) show that ion-exchange buffer can effectively neutralize acids in soils of CEC 7.96–37.42 $cmol_c \cdot kg^{-1}$. In the soils of spring niches CEC is higher. If there is no calcareous or high base saturation, ion-exchange buffer is the main and effective way of acidity neutralization.

Strong influence exerted by SOM, clay content and specific surface area on many soil properties in spring niches is confirmed by the results of statistical analysis (Table 6).
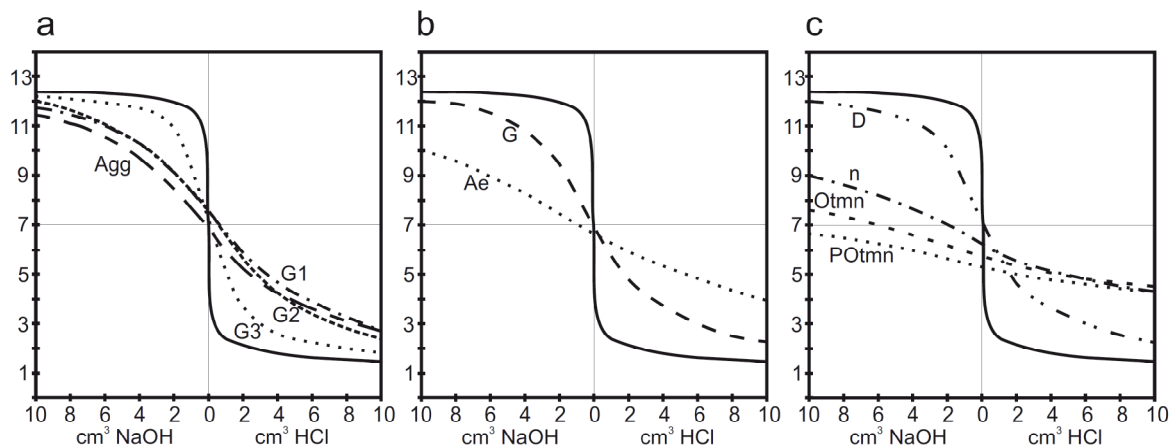
Figure 1. Buffer curves of: a) proper gley soil of niche nr 1, b) peat-like soil of niche nr 3, c) peat-mud soil of niche nr 4; solid line – buffer curve of quartz sand

Table 6. Correlations between SOM concentration, SOM humification rate, clay content, specific surface area and some chemical properties of the soils ($p < 0.05$)

Soil chemical properties	SOM	Humification rate	Clay content	Specific surface area
TON	0.98	–	0.77	0.72
N_h	0.84	–	0.70	0.82
DON	0.81	–	0.75	0.59
$N–NO_3$	0.69	–	0.90	0.65
P_t	0.65	–	–	–
P_{pa}	–	–	–	–
P_a	0.77	–	0.80	0.67
K_t	–0.80	–	–	–0.58
K_{pa}	–	–	–	–
K_a	0.54	–	–	–
CEC	0.93	–	0.70	0.84
Ex Ca*	0.92	–	0.70	0.82
Ex Mg*	–	–	0.72	0.71
Ex Na*	0.86	–	0.69	0.70
Ex K*	–	–	–	–
Ex H*	0.88	–	0.68	0.70
Ex Al*	0.92	–0.60	–	0.63

– lack of correlation
* exchangeable Ca, Mg, Na, K, H, Al

4. Conclusions

The performed analyses may lead to the following conclusions:

The water surplus is typical of spring niches' ecosystems and leads to the development of hydrogenic and semihydrogenic soils of different profile thickness.

In general, the characteristic feature of soils in spring niches is high concentration of SOM, which is slightly humified. In the fractional composition of SOM, humic acids dominate in relation to fulvic acids. Humic acids have low aromaticity.

Soils of spring niches are rich in all forms of N, P and K, and poor in plant-available and water-extractable forms of these elements. The observed low content of plant-available and water-extractable forms of N, P and K is caused by permanent leaching of mineralization products by lotic water.

High concentration of SOM in the soils of spring niches has positive impact on soil sorption and buffer properties. The highest values of CEC were noticed in organic horizons of peat-mud soils. The ionic composition of the soil sorption complex was determined by the feeding water chemistry. Almost total base saturation of the soil sorption complex was observed in every niches. Calcium was the basic cation.

In the situation of a very low content of carbonates, ion-exchange buffer was a basic mechanism neutralizing the acids. The ion-exchange buffer was very effective due to high CEC and high base saturation.

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