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BUFFER ABILITY OF PODHALE SOILS

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A b s t r a c t. In this paper the results of buffer ability investigations of 10 profiles of the Podhale region are presented. Buffer curves are plotted - buffer capacities and buffering areas are calculated for them. The obtained results were compared with some physico-chemical properties. It was found that the soils of Podhale region belong mainly to strongly buffered soils and their base-buffering ability is higher than acid-buffer one. The differences of the buffering degree are caused first of all by different mechanical composition, the content of humus and carbonates, and the degree of base saturation. Buffer areas are significantly correlated with sorption properties of the soils. The highest buffer ability is in alluvial and deluvial soils (among the tested soils) and the lowest one is in forest podzolized acid brown soils. Knowledge of buffer abilities of these soils is very important because of high precipitation (with the low pH of rainfall) in this region.

K e y w o r d s: buffer ability of soil, soils of Podhale region

INTRODUCTION

The annual precipitation in Podhale region is about 1200 mm with average pH 4.2 (data from Zakopane in 1989-1991). Buffer ability of soils determines their resistance to degradation caused by acid rains, and that is why knowledge of the buffering degree in soils of that region is important.

There are some buffer systems of soil function at the same time like: carbonate, siliceous, ion exchange, aluminium, ferric (by Ulrich [o.c. after 8]). Their functioning depends generally on physico-chemical properties of the soil such as: mechanical composition (particularly the content of colloidal clay fraction), humus content, soil reaction and the content of base exchange cations and hydrolytic acidity. In the earlier paper on the soils of Podhale [7], the courses of the buffering curves were determined after the Arrhenius method [2] and they were ascertained in some soils belonging to various taxonomic units with diversified physico-chemical properties. In this paper, we try to be precised about the relationship between buffer abilities of specific Podhale soils, which are determined by buffering areas and buffer capacities, and their physico-chemical properties.

MATERIALS

The samples were taken from 10 soil profiles, representative for Podhale, and their location is presented in Fig. 1. Most of the tested soils occur in non-forest plant associations (profiles 1-9); only profile 1 is represented by forest soil (Table 1). These soils display the following types and subtypes: brown soils (profiles 2, 8), acid brown soils (profile 1), gley-podzols (profile 9), gley soils (profiles 3 and 4), pseudogley soils (profile 5) and river alluvial soils (profiles 6, 7, 10). They are derived from the formations like: flysch (profiles 1, 2, 8), moraine (profile 9), glacifluvial (profiles 3, 5), alluvial (profiles 6, 7, 10) and deluvial (profile 4), (Table 1).

Table 1. Locality, rocks and typology of the tested soils and their plant communities

Profile No.	Locality Altitude	Rock	Vegetation	Type and subtype
1	Bielanka 750 m a.s.l.	Flysch	Piceetum- -Abietetosum	Podzolized acid brown soil
2	Bielanka 700 m a.s.l.	Flysch	Hieracio- -Nardetum	Leached brown soil
3	Pieniążkowice 550 m a.s.l.	fluvioglacjal sediments	fresh damp meadow	Proper gley soil
4	Maruszyna 600 m. a.s.l.	deluvial sediments	wet meadow partially swampy	Mud-gley gley soil
5	Białka 860 m a.s.l.	fluvioglacial sediments	grown ower fallow, habitat of poor pasturage	Proper pseudo-gley soil
6	Białka 870 m a.s.l.	alluvial sediments	Petasitetum kablikiani	Proper alluvial soil
7	Skrzypne 650 m a.s.l.	alluvial sediments	Alnetum- -incanae	Brown alluvial soil
8	Stasikówka 960 m a.s.l.	Flysch	arampled community with Plantaginetea maioris	Leached brown soil
9	Antałówka 915 m a.s.l.	moraine sediments	Nardo-Juncetum	Proper gley-podzol
10	Chochołowska Valley 905 m s.a.l.	alluvial sediments	Gladiolo- -Agrostitum	Brown alluvial soil

Buffer abilities of soils and some their physico-chemical properties were determined in all horizons of the tested profiles. The Arhenius method [2] as modified by Brenner [3] and Kappen [4] was applied to determine buffering using 0.1 mol HCl and 0.1 mol NaOH. Buffer curves were plotted on the base of pH measurements in the solutions obtained after the methods described above. Buffer ability expresses an inclination grade of a curve to the axis of abscissae (the lower inclination grade of a curve the higher buffer ability), the area between a buffer curve and the standard one (for pure sand) (using planimetric method) and buffer capacity. Buffer capacity is assumed as the quantity of millimole of acid or base necessary to change the pH of one cube decimetre of soil by one unit. The remaining properties were determined by prevailing methods using in soil science.

RESULTS

Mechanical composition of the tested soils is differentiated - from light clayey sand to clay. The soils derived from Magura sandstones belong to the light soils (profiles 1, 2) and alluvial formations (profiles 6, 7, 10), as well as some soils derived from glacifluvial formations (profile 3). These soils contain from 4 to 16 % of colloidal clay fraction (Table 2). The soils derived from Podhale flysch (profile 8), and moraine (profile 9), glacifluvial (profile 4) and deluvial formations (profile 5) belong to the heavy soils (heavy loam, clay). The soils contain

Table 2. Some physico-chemical properties of the tested soils

Profile No.	Horizon	Depth cm	% of fractions with diameter in mm 1.0—0.1	0.1—0.02	0.02—0.002	<0.002	pH KCl	Organic C %	S cmol(+)/kg	Hh cmol(+)/kg	P_{NaOH}	P_{HCl}	mmol NaOH/dm^3	mmol HCl/dm^3
1	0	0-8	-	-	-	-	3.2	37.1	-	39.0	22.0	3.7	85.3	85.3
	AhEes	8-12	50	31	9	10	3.5	2.5	1.4	9.8	23.5	1.3	45.7	53.3
	Bbr	12-31	46	26	19	9	4.2	0.6	1.6	5.6	29.4	0.2	28.6	59.8
	BbrC	31-55	50	26	16	8	4.1	0.4	1.0	3.8	30.9	1.5	27.8	89.0
2	Ah	0-8	39	29	21	11	4.5	1.0	2.5	6.8	21.6	5.7	45.0	59.3
	AhBbr	8-42	56	28	17	9	4.3	1.3	3.1	7.2	21.8	4.2	37.6	55.7
	BbrC	42-68	37	30	23	10	4.5	0.6	2.7	5.4	20.3	6.6	43.3	68.4
3	Ah	0-13	35	29	22	14	4.3	2.6	3.5	3.6	23.5	6.0	42.4	58.6
	Ahgg	13-33	38	26	21	15	4.2	0.4	3.1	2.4	21.9	3.4	38.4	43.9
	Gax	33-50	39	26	19	16	4.3	0.3	3.1	1.7	19.0	3.0	41.4	40.2
	G	50-72	43	32	11	14	4.2	0.2	5.3	1.3	15.5	4.5	33.7	43.8
	AbG	72-100	52	24	13	11	4.6	0.8	5.2	2.0	16.8	6.2	39.2	43.3
4	Ah	0-16	6	33	31	30	6.7	4.1	33.7	0.4	16.1	25.6	211.7	254.0
	AeG1	16-62	6	35	38	21	6.3	1.9	15.6	0.4	12.8	16.2	101.2	37.6
	AeG2	62-88	6	33	38	23	5.6	3.3	15.9	1.1	16.6	14.3	90.7	43.8
	AeG3	88-110	-	-	-	-	5.5	4.5	-	-	16.5	15.4	154.4	38.6
	Ae	110-125	-	-	-	-	-	11.5	-	-	20.0	16.9	94.6	66.8
5	Ah	0-10	11	32	38	19	3.7	2.1	2.2	7.0	21.4	5.5	56.3	44.7
	Gg	10-65	11	29	40	20	3.7	0.4	1.8	4.7	23.2	5.6	57.4	44.0
	Bg	65-115	11	29	36	24	3.6	0.3	5.8	3.4	22.1	5.3	41.7	58.0
	BC	115-140	25	21	36	18	3.8	0.3	5.9	1.0	-	-	-	-
6	AhC	0-7	-	-	-	-	6.7	2.3	8.8	0.4	12.6	21.0	62.1	100.4
7	Ah	0-19	37	31	19	13	4.4	6.0	8.6	5.3	19.0	8.0	43.6	55.5
	IIBbrC	19-29	70	10	13	7	6.7	0.6	10.6	0.4	12.0	24.6	55.4	190.0
8	Ah	0-14	14	31	40	15	3.8	3.4	9.1	9.2	23.0	7.5	52.5	54.8
	AhBbr	14-45	16	23	28	33	4.0	1.4	4.1	12.0	255.0	6.9	68.4	61.9
	BbrC	45-90	13	27	35	25	3.9	0.4	4.1	7.8	22.0	5.5	72.8	65.0
	C	90-200	30	25	25	20	6.6	0.3	3.8	0.9	11.6	20.7	80.4	68.5
9	Otmsz	0-15	-	-	-	-	-	38.9	-	-	26.0	3.0	147.8	113.3
	AeEeS	15-23	18	31	32	19	3.3	3.7	-	6.0	27.8	3.5	67.5	60.8
	Eesg	23-36	17	22	32	29	3.5	1.6	-	6.1	26.7	5.5	77.1	52.4
	Bg	36-58	10	20	41	29	3.8	0.6	-	10.7	23.5	8.0	85.0	77.4
	BgC	58-78	14	16	36	34	3.6	0.4	-	9.9	24.8	5.1	66.3	77.3
10	Ah	0-8	28	43	20	9	5.1	6.8	22.9	6.9	16.4	12.4	92.1	36.8
	AhBbrg	8-13	30	29	25	16	4.9	4.1	16.4	8.1	18.2	10.8	68.1	47.1
	BbrC	13-26	79	10	7	4	5.7	0.7	6.9	1.4	14.8	8.3	61.2	30.6
	C	26-60	71	14	10	5	5.9	0.6	9.2	1.6	12.8	9.9	44.8	32.2

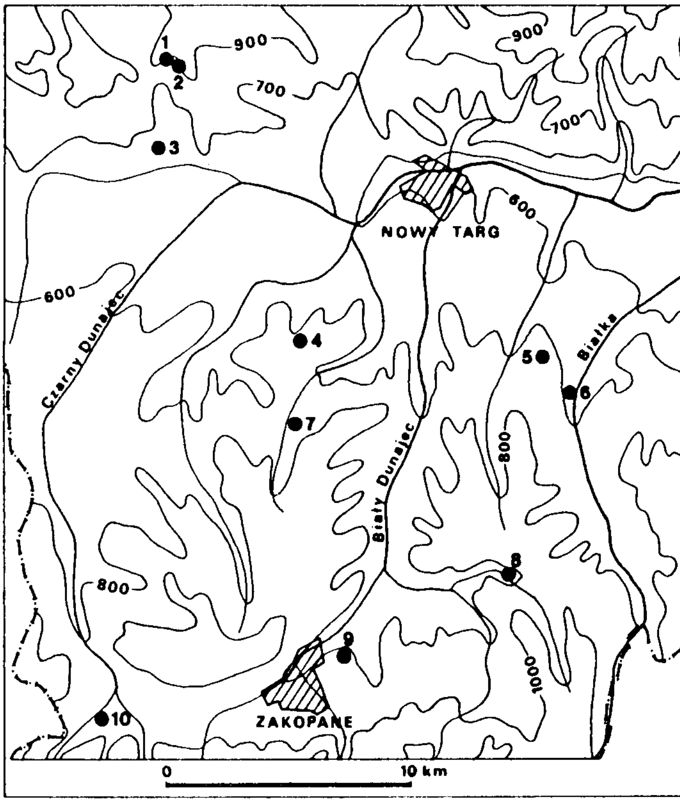

Fig. 1. Location of tested soils (1-10 - profile numbers).

from 15 to 34 % of colloidal clay fraction (Table 2).

Most of the tested soils (profiles 1, 2, 3, 5, 9) is very acid (pH KCl 3.8-4,6). The surface horizons of two profiles (profiles 7, 8) are very acid but lower horizons, for reason of little content of carbonates (per cent CO_2carbonateis respectively 0.83 and 0.09) are neutral (pH KCl 6.6-6.7). The pH increases with depth in most of tested profiles. The contrary is found in profile 5 and it is caused by alkaline inflow from the calciferous slopes of Żdżar (Table 2).

Organic carbon content of the tested soils is very differentiated. It is ranged from 1.0 to 6.8 % in humus horizons. The higher content of C organic is in organic horizons of profiles 1 and 9 (respectively 37.1 and 38.9 %).

Absorbing capacity in most of horizons of tested soil profiles, according to division introduced by Lityński [5] is very strong, it is over 9 cmol(+)/kg of soil. The lowest one but still in ranges proposed by Lityński for medium and higher buffer capacities occurs in profile 3. It is connected with the lower humus content and the content of medium colloidal clay fraction.

Total exchangeable bases and hydrolytic acidity are very different in each horizon and they are closely correlated with the reaction and the content of humus (Table 2).

In general, the inclination grade of buffer curves to X-axis, expressing buffer ability of the tested soils, is not high. It is different for curves of various soil profiles, and even for curves of each horizon of the same profile (Figs 2 and 3). Usually the curve of humus horizons is visibly less inclinated. A part of a curve which illustrates acid-buffering of soil is often slightly inclinated to X-axis than a part presenting base-buffering. However, analysing

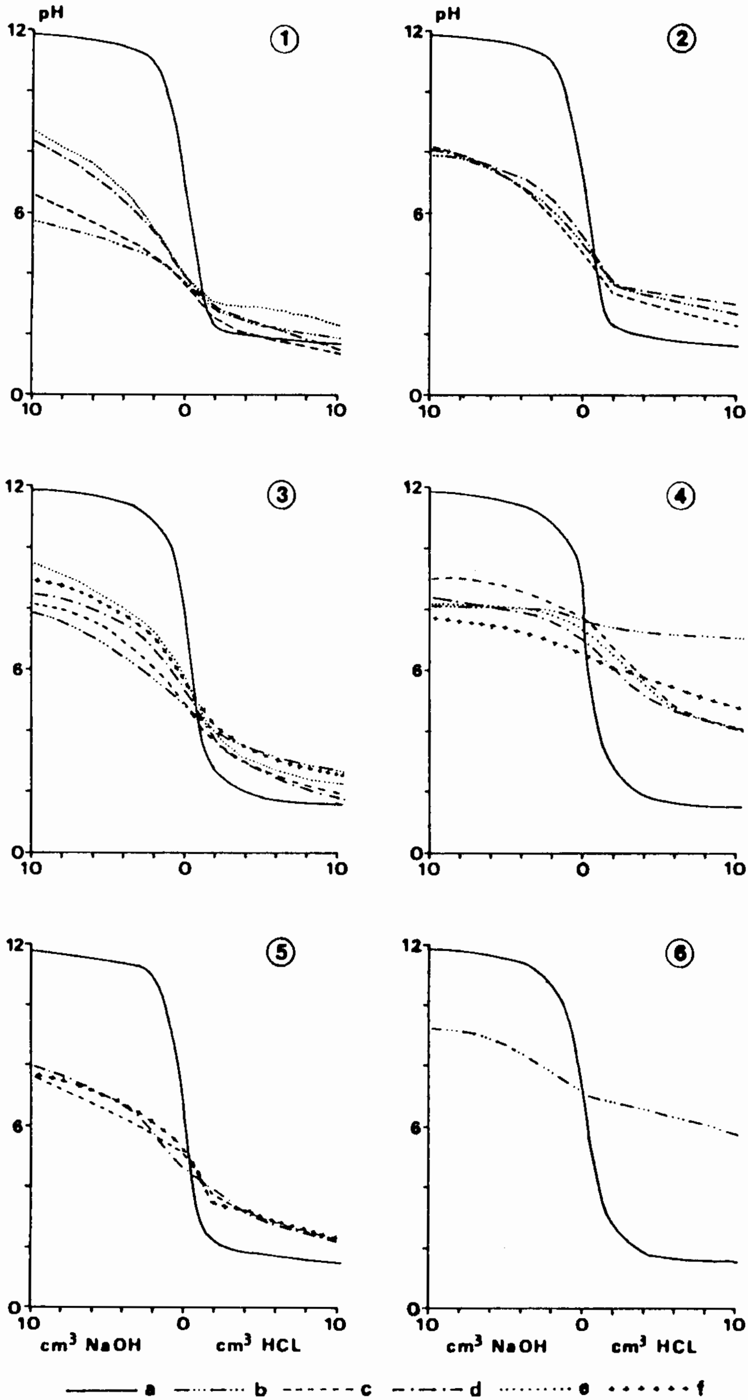

Fig. 2. Buffer curves of separated horizons of profiles 1-6: a - model curve, b-f - horizons (in order from surface to foot of soil profile).

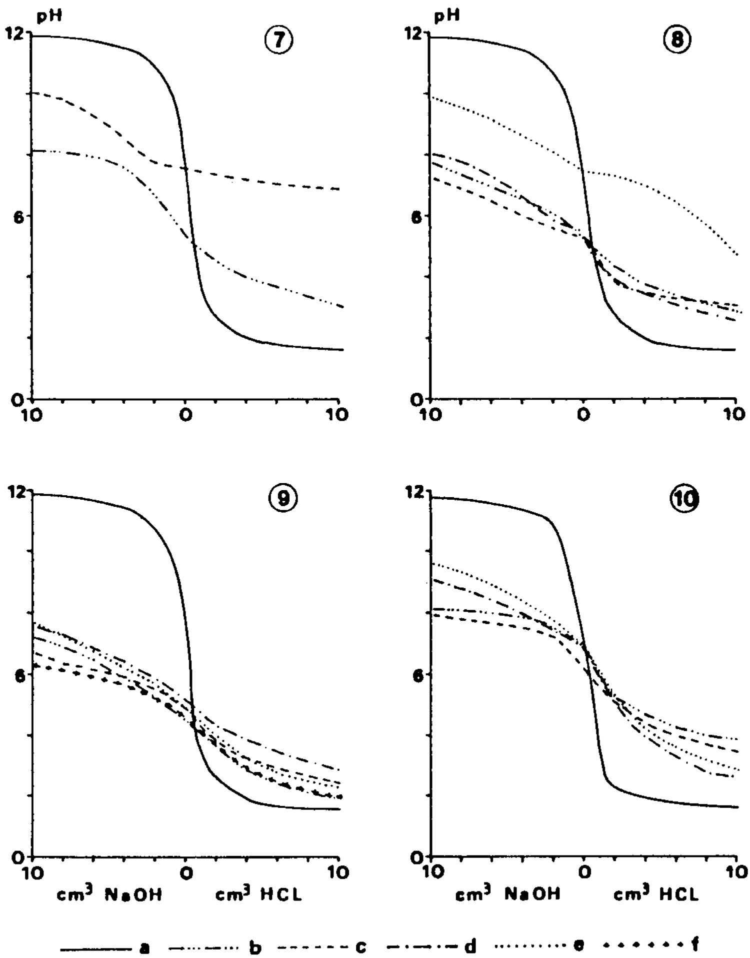

Fig. 3. Buffer curves of separated horizons of profiles 7-10: a - model curve, b-f - horizons (in order from surface to foot of soil profile).

all courses of the curves for separated profiles it is found that the inclination grade is the highest in profile 10 and gradually decreases in profiles 3, 2, 1, 8, 9, 5 but rapidly decreases in profiles 4, 6 and 7.

Areas enclosed between the buffer curve and the model one (it is equal at all figures) depend on initial reaction of soils (determined in water) and the inclination grade of buffer curve. The larger area the higher buffer ability of the soil. The areas pointing to base-buffering of tested soils are usually higher (1.1-20.6 times) than adequate areas characterizing effect of acid. In five horizons of profiles 4, 6, 7 and 8 with the highest pH KCl which ranges from 6.3 to 6.7, this dependence is contrary, i.e. that acid-buffer areas are higher (1.3-2.1 times) than corresponding base-buffer areas. The areas which chracterizebase-buffer (P_{NaOH}) vary between 11.6 and 30.9 cm2, but in four soils (in order from the highest to the lowest - profiles 1, 9, 5, 2) and in some horizons of profile 3 and 8 they exceed 20 cm^2. The areas which characterize acid-buffer (P_{HCl}) are lower and range from 0.2 (for the forest soil - profile 1) to 25.6 cm^2, only in four horizons with neutral reaction - profiles 4, 6, 7, 8 they exceed 20 cm^2.

Acid- (B_{HCl}) and base-buffer (B_{NaOH})

capacities of the tested soils are most often close to each other (Table 2). It is because of the way of their calculation. In the strongly acid soils acid-addition of acid causes inconsiderable changes of pH values. Then the quantity of millimole necessary to change pH of 1 dm^3 of soil by unit is very high, the more so as it applies to soils with lower density of solid phase.

DISCUSSION

Buffer curve courses determined for particular soil profiles and their horizons are not equal. It is a result of different physico-chemical properties of investigated soils. The least inclinated curves are for alluvial and deluvial soils (profiles 4, 6, 7, 10) and in comparison with the other they are a little lighter but humus content is high and the degree of base saturation is considerable (V % ranges from 62.1 to 98.8). The content of carbonates is inconsiderable but with high buffer potentiality [9]. These soils in comparison with the rest have higher buffer capacities and larger buffering areas. Their acid-buffering ability is distinctly higher than base-buffering one, though it is necessary to state that their base-buffer capacities (B_{NaOH}) is higher than in soils of the Niepołomice Forest [1] which have similar reaction and mechanical composition. Buffering areas (P_{NaOH}) of humus horizons of these soils are also distinctly higher than buffering areas determined by Pokojska [8] in comparable horizon with droso-mull type of humus from Ostrów Panieński reserve. Therefore, the soils under discussion have significant resistance to the acid effect and only non-significantly lower to the base one.

Buffer curves of the other soils (profiles 1, 2, 3, 5, 8, 9) are strongerly inclinated to X-axis and it means that their buffering is slighter, i.e. they have lower buffer capacities and smaller buffering areas. These values vary significantly in each horizons and this is connected with their different humus content, colloidal clay fraction and base cations. Frequently, a part of the curve illustrating the acid effect is lower inclinated than this one for base. It isses from the lowest reaction of that soils. If the pH is lower than 4.0 further addition of acid changes it only a little. Therefore, for some horizons (profiles 1, 9) with small buffering areas, high values of buffer capacity are calculated.

The tested soils contain comparatively a lot of colloidal clay fraction and humus, so they often have 'very strong' buffer capacity (the degree after Lityński). In this case, high effect of ion exchange buffer (by Ulrich, [o.c. after [8]) on buffer abilities of the tested soils is expected. Because of high accumulation of aluminium and iron which is connected with gley process and very low reaction an effect of aluminium and ferric buffer is also expected.

Exchange capacity of the soil is strongly and significantly correlated to its buffer capacity (r_6= 0.612) and buffering area (r_3= 0.484), (Table 3). The more so as close correlation between total exchangeable bases and acid-buffer capacity, and hydrolytic acidity and base-buffering ability. Whereas, very close correlation exists only between acid-buffering areas and total exchangeable bases (r_2=0.956). However, there is no correlation

Table 3. Correlation coefficients between buffering areas, buffer capacity and sorption properties of the tested

Correlation coefficient	Dependences	N	r	p
r1	P_{NaOH} - Hh	33	0.363	<0.05
r2	P_{HCl} - S	28	0.956	<0.001
r3	P - T	28	0.484	<0.01
r4	B_{NaOH} - Hh	33	0.193	<0.1
r5	B_{HCl} - S	28	0.323	<0.05
r6	B - T	28	0.612	<0.001

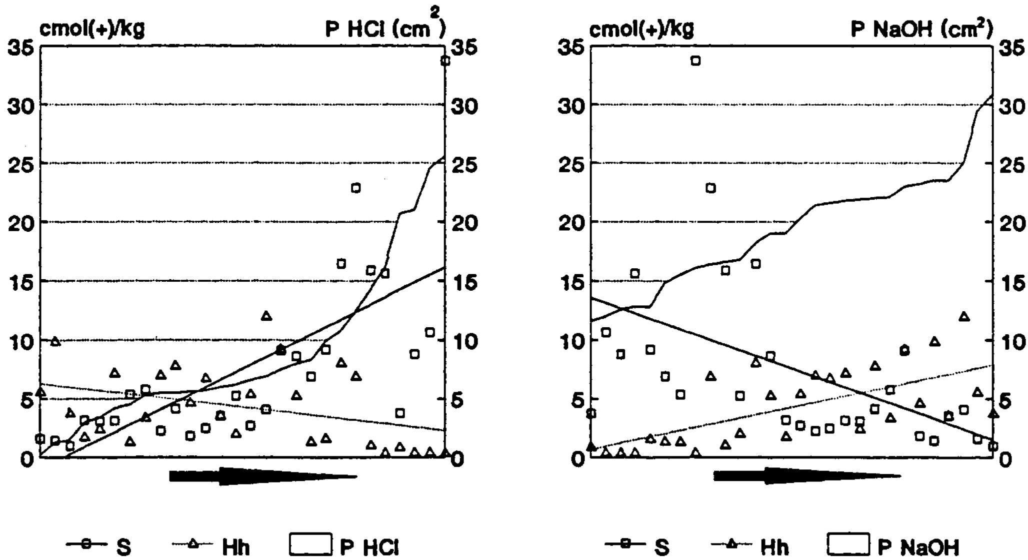

Fig. 4. Dependences between acid-buffering area (P HCl) and base-buffering one (P_{NaOH}), and ion exchangeable base (S) and hydrolytic acidity (Hh). P values are arranged from the lowest to the highest.

between base-buffer capacity and hydrolytic acidity (r_4= 0.193) (Table 3), and lower correlation between base-buffering area and hydrolytic acidity (r_1 = 0.363). It may be explained by the effect not only of ion exchange buffer but also of the other buffer systems. Significantly correlated dependences, as well positively as negatively, are illustrated at Fig. 4.

CONCLUSIONS

1. Strongly buffered soils occur in the Podhale region and their base-buffering ability is higher than acid-buffering one.

2. Alluvial soils are the most resintant against the pH changes which are caused by acid and base effects.

3. The forest soil has the lowest acid-buffering ability.

4. Ion exchange buffer have the greatest role of buffer abilities of the tested soils. Aluminium and ferric buffer have also great importance particulary in acid gley soils, and carbonate buffer in the soils containing carbonates.

5. Buffering area is probably the best indication of buffer abilities.

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ZDOLNOŚĆ BUFOROWA GLEB PODHALA

W pracy przedstawiono wyniki badań zdolności buforowej gleb z dziesięciu profilów glebowych Podhala. Wykreślono dla nich krzywe buforowe, obliczono pojemności buforowe i powierzchnie buforowania. Uzyskane dane porównano z niektórymi właściwościami fizykochemicznymi gleb. Stwierdzono, że gleby Podhala należą w większości do silnie zbuforowanych i mają większą zdolność buforowania zasad aniżeli kwasów. Różnice w stopniu zbuforowania poszczególnych gleb wynikają przede wszystkim z ich różnic w: składzie granulometrycznym, zawartości próchnicy i węglanów, oraz stopniu wysycenia kompleksu sorpcyjnego zasadami. Wielkość powierzchni buforowych jest więc istotnie skorelowana z właściwościami sorpcyjnymi gleb. Największą zdolność buforowania kwasów, spośród badanych gleb, wykazały gleby napływowe, a najmniejszą, leśne gleby brunatne kwaśne bielicowane. Znajomość zdolności buforowych gleb tego regionu jest bardzo ważna w związku z występowaniem tu dużej ilości opadów o niskim pH.

S ł o w a k l u c z o w e: zdolność buforowa gleby, gleby Podhala.