УДК 631.4

TAXONOMIC POSITION OF SALT-AFFECTED SOILS CONTAINING REDUCED FORM OF SULPHUR

P.Hulisz*, A.Piernik**

**Department of Soil Science, Institute of Geography,*
***Laboratory of Ecological Modelling, Institute of Ecology and Environmental Protection*
Nicolaus Copernicus University, Poland, hulisz@umk.pl

The investigations involved inland salt-affected soils containing reduced form of sulphur. The taxonomic position according WRB classification (2006) was determined on the basis of main soil properties, salinity and sodicity state. These soils showed the similarity to potential acid sulphate soils. That is why the distinguishing of *sulphidic* material for all pedons was possible. Also the modification of qualifiers list for Solonchak Reference Soil Group (RSG) was proposed.
Keywords: potential acid sulphate soils, salt-affected soils, soil acidification, sulphur, WRB classification

Introduction. Potential acid sulphate (PASS) and acid sulphate (ASS) soils are formed in very specific geochemical conditions, mainly under the influence of sea water. Strong acidification caused by oxidation of iron sulfides affects both soil and water, and can damage the environment severely [1, 5, 6, 12].

PASS and ASS occupy very small areas in Polish Baltic zone. These are both organic and mineral-organic soils with different salinity and sodicity level [20, 21]. Nowadays they are mostly protected in the framework of Nature 2000 network as an integral part of rare saline habitats [7]. The detailed proposal of PASS and ASS classification was given by Pracz [19]. Unfortunately, such soils are not distinguished in Systematics of Polish soils [23].

Soils with properties similar to PASS beyond Baltic seacoast was so far mentioned only by Czerwiński [4]. It seems that the primary source of SO_4^{2-} ions is saline groundwater in areas mainly influenced by salt tectonics (Permian and Miocene deposits). Further transformation of sulphur is strictly connected with microbiological and chemical processes, analogically like in soils directly affected by seawater.

The aim of the present paper is the analysis of the properties of inland salt-affected soils containing reduced form of sulphur with regard to their taxonomic position.

Object and methods. The study was conducted in 2005 year. Three pedons were selected on the basis of field pH test with 30% hydrogen peroxide [11]. Figure 1 shows the location of soil pits: 1 - Solnia, 2 - Trzcianki (Warta River valley, Central Poland) and 3 – Baranow (Nida Basin, South Poland).

Standard soil analyses were performed according to the methods as follows: organic carbon content (Corg) - by sample oxidation in the mixture of $K_2Cr_2O_7$ and H_2SO_4, total nitrogen content (N_t) – Kjeldahl method, total sulphur content (S_t) – Eschka method, $CaCO_3$ content – Scheibler volumetric method and grain size distribution – by hydrometer and sieve method. These procedures can be accepted as compatible with those suggested by WRB classification.

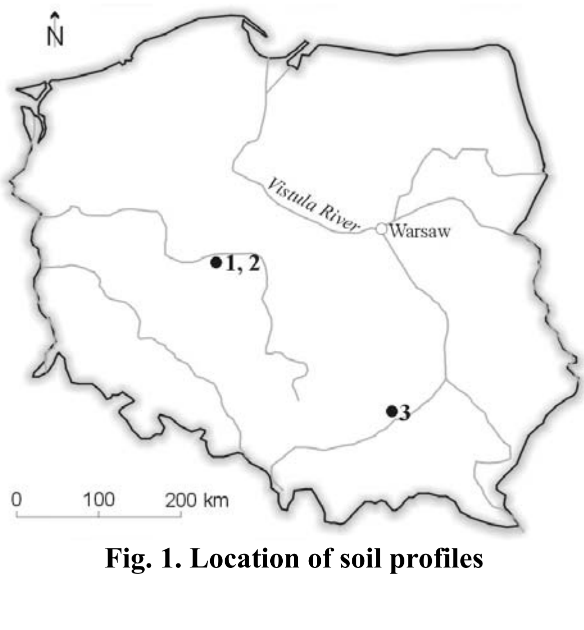

Fig. 1. Location of soil profiles

Soil reaction (pH in H_2O) was measured potentiometrically in fresh soil sample, after 8 weeks incubation and after oxidation with 30% H_2O_2 [11].

Electrical conductivity (EC) at 25^0C, pH and the main ions (Ca^{2+}, Mg^{2+}, Na^+, Cl^-, SO_4^{2-}, HCO_3^-) content were determined in water samples and in soil paste saturation extract. The results were the base for sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) calculation [24].

Soil colour was determined in moist and dry sample using Munsell Revised Standard Soil Colour Charts [22].

The vegetation in the surrounding of pedons was described by Braun-Blanquet method [2]. The types of habitats were elaborated according to Natura 2000 typology [17], plant associations and communities according to Matuszkiewicz [14], the names of plants species followed Mirek et al. [15].

Investigated soils were classified according to World Reference Base for Soil Resources classification criteria [10, 11].

Results and their discussion. Soils in three study sites were affected by shallow saline groundwater, which level was average within 0.5-1 m from the terrain surface. Some ground area can be also periodically flooded. The results of groundwater analysis, taken from soil pits, are shown in Table 1. Reaction was weakly alkaline (pH 7.7 - 8.3) and EC values varied from 2.52 to 31.3 $dS \cdot m^{-1}$.

1. Properties of the groundwater

Locality	Profile No.	pH	EC $dS \cdot m^{-1}$	HCO_3^-	SO_4^{2-}	Cl^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	SAR	Hydrochemical type*
				$mg \cdot dm^{-3}$								
Solnia	1	8.3	2.52	189	72.7	560	400	10.7	53.3	15.7	12	Cl-Na
Trzcianki	2	7.7	8.56	262	268	2250	1220	11.4	328	78.7	16	Cl-Na-Ca
Baranow	3	7.7	31.3	458	3440	9660	6100	280	763	587	40	Cl-SO_4-Na

* *according to Shchukarev-Priklonsky classification [13]*

SAR index (12-40) pointed to high and very high sodium hazard. The richest in sulphate ions waters occurred in Baranow – profile 3 (3440 $mg \cdot dm^{-3}$), what was additionally correlated with hydrochemical type of water (Cl-SO_4-Na).

The studied soils was characterized by the presence of muck (profile 1-2) and mud (profile 3) horizons. First of them overlayed loose terrace sands (tab. 2). The presence of *gleyic colour pattern* in lower parts of profiles 1-2 pointed to the relatively permanent wet conditions. The reductimorphic colours predominated, respectively 2.5Y 2/1 and 2.5YR 3.5/1. Some soil horizons showed red-yellow mottling (profile 2: Clnz1 – 10% mottles 10YR 6/6, Clz2 – 35% mottles 10YR 6/6). Some accumulation of pyrite in profile 1 (fig. 2) also pointed to *reducing conditions*.

2. Texture and colour of studied soils

Profile No.	Horizon	Depth, cm	Particle size distribution, %			Colour	
			(2 mm - 50μm)	(2-50 μm)	(< 2 μm)	moist	dry
1	Hnz	0-32	-	-	-	10YR 2/2.5	10YR 3/1
	Ahnz	32-51	-	-	-	10YR 1.7/1	10YR 2/1
	Ahz1	51-64	-	-	-	10YR 2/2	10YR 2.5/2
	Ahz2	64-90	95	4	1	10YR 1.7/1	10YR 2.5/1
	Crz	90-104	98	2	0	2.5Y 2/1	2.5Y 4/1
2	Hz	0-15				7.5YR 2/2	7.5YR 3/1
	Ahnz	15-20	94	6	0	7.5YR 1.7/1	7.5YR 2/1
	Clnz	20-33	97	3	0	10YR 6/2*	10YR 7/1
	Clz	33-81	100	0	0	10YR 6/2**	10YR 7/1
	Crz	81-102	100	0	0	2.5YR 3.5/1	2.5YR 5.5/1
3	Hnz	0-21	-	-	-	10YR 1.7/1	10YR 3/1
	Ahnz	21-50	-	-	-	10YR 3/1	10YR 3.5/1

* *10% mottles of oxymorphic colour (10YR 6/6)* ** *35% mottles of oxymorphic colour (10YR 6/7)*

Significant organic carbon content (14.1-17.0%) in surface horizons was stated (tab.3). Because of too small thickness (15 cm) and Corg content (14.8%) it was impossible to distinguish *histic* horizon in profile 2. However, the properties of this soil corresponded to Hyperhumic qualifier. The rest of the pedons fulfilled criteria for *organic material* and Histic qualifier. Total sulphur content (S_t) was between 0.08 and 3.62% (tab. 3). In surface and subsurface horizons of profiles 1-2 S_t values strictly correlated with Corg content (C:S ratio from 32 to 66). Lower C:S ratio in deeper soil horizons suggested the significant contribution of mineral forms of sulphur. Because of poor soil buffering (lack of carbonates, coarse texture) strong acidification of samples after incubation and treatment with 30% H_2O_2 was noted. The highest pH drop was observed in Crz horizons, maximally more than 4 units (fig. 2). It is necessary to emphasize that in spite of relatively low S_t content (respectively 0.24 and 0.28%) pH of oxidized samples was lower than 4.0, limited value used to diagnose of *sulphidic* material. The last criterion was added to first update of WRB 2006 classification [11]. Undoubtedly, it gives the better possibility to classify PASS developed from mineral, loose parent material.

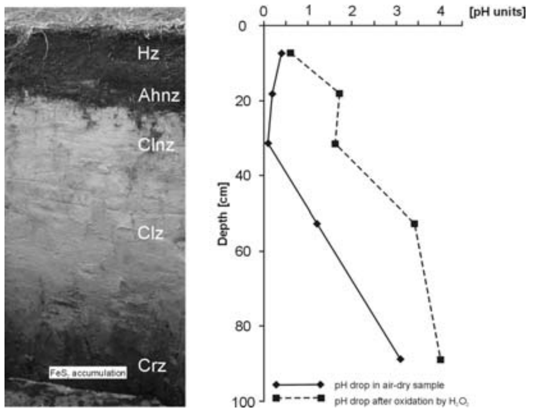

Fig. 2. An example of the soil with visible accumulation of pyrite (profile 2)

3. Chemical properties of studied soils

Profile No.	Horizon	Depth cm	pH in H_2O			Corg	N_t	S_t	C:N	C:S
			fresh sample	air-dry sample	after oxidation H_2O_2	%				
1	Hnz	0-32	7.0	6.6	6.4	14.1	1.12	0.32	13	44
	Ahnz	32-51	7.1	6.9	5.4	7.68	0.450	0.24	17	32
	Ahz1	51-64	6.6	6.5	5.0	8.51	0.494	0.48	17	18
	Ahz2	64-90	6.6	5.4	3.2	4.08	0.230	0.36	18	11
	Crz	90-104	6.5	3.4	2.5	0.69	0.028	0.24	-	3
2	Hz	0-15	7.3	6.8	6.7	14.8	1.46	0.25	10	59
	Ahnz	15-20	7.5	7.3	7.2	3.41	0.310	0.08	11	43
	Clnz	20-33	7.9	7.9	7.5	0.51	0.047	0.08	11	6
	Clz	33-81	7.8	7.7	5.8	-	-	0.08	-	-
	Crz	81-102	7.2	3.2	2.7	-	-	0.28	-	-
3	Hnz	0-21	7.0	4.4	3.1	17.0	1.35	3.62	13	5
	Ahnz*	21-50	7.2	7.1	7.1	5.88	0.519	2.02	11	3

******$CaCO_3$ content 4.77%*

Total sulphur content in profile 3 (3,62% in Hnz and 2,02% in Ahnz) was higher than typical values for soils in Poland. After Motowicka-Terelak and Terelak [16], the average range of S_t values in mineral-organic and organic soils is between 0.05 and 0.67%. It is worth to notice that the strong acidification of soil sample under the laboratory condition was occurred only in Hnz horizon. It suggested too low primary carbonate content to neutralize of released hydrogen ions (on the contrary to Ahnz - tab. 3). This horizon fulfill the criteria for *sulphidic* material.

Electrical conductivity of the saturation extract (EC_e) ranged from 2.06 to 56.1 $dS \cdot m^{-1}$ (tab.4). First two soils fulfilled criteria for Hyposalic qualifier ($EC_e > 4\ dS \cdot m^{-1}$). However, the diagnostic *salic* horizons was presented in profile 3 within upper 50 cm. Some horizons, especially Hnz and Ahnz in profile 3, were riched in exchangeable sodium. High sodicity level in all soils allowed to use Sodic qualifier (ESP>15%).

4. Properties of saturation extract

Profile No.	Horizon	EC_e	Thickness EC_e	SAR	ESP*
		$dS \cdot m^{-1}$	$cm \cdot dS \cdot m^{-1}$		%
1	Hnz	3.63	116	13	15
	Ahnz	3.61	69	13	16
	Ahz1	4.47	58	9	10
	Ahz2	6.12	159	5	5
	Crz	5.33	75	2	2
2	Hz	12.1	182	7	8
	Ahnz	7.92	40	13	15
	Clnz	4.86	63	14	16
	Clz	2.06	99	6	7
	Crz	7.29	153	3	3
3	Hnz	56.1	1178	52	43
	Ahnz*	33.6	974	32	32

**calculated from SAR [23]*

In the studied areas halophilous vegetation occurred as field indicator of saline soils. *Scirpetum maritimi puccinelietosum* subassociation was typical for Solnia and Baranów sites, whereas *Triglochino-Glaucetum maritimae* association for Trzcianki. These both types of vegetation according to Natura 2000 nomenclature are called “Inland saline meadows and reeds” with code *1340 [17]. The following halophilous plant species were present in the investigated places: *Atriplex prostrata* ssp. *prostrata* and *Schoenoplectus tabernaemontani* in Solnia, *Bolboschoenus maritimus*, *Spergularia salina*, *Atriplex prostrata* ssp. *prostrata* and *Puccinellia distans* in Baranow, *Glaux maritima* and *Triglochin maritimum* in Trzcianki site. The last two ones indicate soil salinity over 4 $dS \cdot m^{-1}$ [18]. However the vegetation of the investigated sites was similar to other saline places [9]. In case of profile 3 where the surface horizons riched in mineral sulphur occurred, it could not be an indicator of PASS.

Taking into consideration properties of the studied pedons their taxonomic position according to WRB was established:

1- Hyposalic Histic Gleysol (Sodic, Protothionic)
2- Hyposalic Gleysol (Sodic, Protothionic)
3- Histic Hypersalic Solonchak (Sodic)

Unfortunately, in case of profile 3 it was impossible to use Thionic qualifier (exactly Protothionic), because it is not on the list of qualifiers for Solonchaks. It could be considered to add this qualifier to list for this RSG in next edition of WRB what would allow to give better taxonomic description for strong saline soils with accumulation of sulphides.

Conclusions. Inland salt-affected soils under the study showed some properties similar to PASS. Very high pH drop in samples after incubation or treating by H_2O_2 and low C:S ratio suggested the presence of mineral sulphur forms in horizons affected by shallow groundwater. The first update of WRB 2006 [11] gives the better possibility to emphasize specific features of these soils on the second level of classification than the previous version [10]. However, some limitation in distinguishing *sulphidic* material was stated.

The presented results are the continuation of a discussion about the using of WRB system to classification of salt affected soils in Poland, undertaken in the previous papers [3, 8]. It seems that such studies are necessary not only from point of view of WRB improvement but it is also important for better recognition of inland potential acid sulphate soils. That is why the addition of Protothionic to list of qualifiers for Solonchaks was proposed.

References:

1. **Bloomfield, C., Coulter, J.K.** 1973. Genesis and management of acid sulfate soils. Adv. in Agronomy 25: 265-326.
2. **Braun-Blanquet, J.** 1964. Pflanzensoziologie 3. Aufl.-Springer-Verlag, Wien.
3. **Charzyński, P., Hulisz, P.** 2005. Diagnostic subsurface horizons in Systematics of the Soils of Poland and their analogues in WRB classification. Eurasian Soil Science, 38, suppl. 1: S55-S59.
4. **Czerwiński, Z.** 1996. Salinity of waters and soils in the Kujawy region. Roczn. Gleb. 47. 3/4: 131-143 (in Polish with English abstract).
5. **Dent, D.L., Pons, L.J.** 1995. A world perspective on acid sulphate soils. Geoderma, 67: 263-276.
6. **Giani, L., Kücks, U., Straatmann, M.** 1996. Genese und Klassifikation von Organomarschen der Wesermarsch. Z. Pflanzenernähr. Bodenk. 160: 15-20.
7. **Herbich, J. (ed.)** 2004. Poradniki ochrony siedlisk i gatunków Natura 2000 – podręcznik metodyczny. Siedliska morskie i przybrzeżne, nadmorskie i śródlądowe solniska i wydmy. Ministerstwo Środowiska, W-wa, T1 (in Polish).
8. **Hulisz, P.** 2007. Proposals of systematics of Polish salt-affected-soils. Roczn. Gleb. 58, 1/2: 1-10 (in Polish with English abstract).
9. **Hulisz, P. Piernik, A.** 2005. Multiaspect studies of salt-affected soils with special regard to their rational use and protection. KBN project 3 P04G 042 25 report. Manuscript (in Polish).
10. **IUSS Working Group WRB.** 2006. World Reference Base for Soil Resources 2006. World Soil Resources Reports No. 103, FAO, Rome.
11. **IUSS Working Group WRB. 2007.** World Reference Base for Soil Resources 2006, first update 2007. World Soil Resources Reports No. 103. FAO, Rome.
12. **Langenhoff, R.** 1986. Distribution, mapping, classification and use of acid sulphate soils in the tropics. A literature study. Int. Med. 74, STIBOKA, Wageningen.
13. **Macioszczyk, A.** 1987. Hydrogeochemia. Wydawnictwa Geologiczne, Warszawa (in Polish).
14. **Matuszkiewicz, W.** 2001. Przewodnik do oznaczania zbiorowisk roślinnych Polski. Vademecum Geobotanicum. PWN, Warszawa (in Polish).
15. **Mirek, Z., Piękoś-Mirkowa, H., Zając, A., Zając, M.** 2002. Flowering Plants and Pteridophytes of Poland – a Checklist. Biodiversity of Poland vol. 1, Kraków.
16. **Motowicka-Terelak, T., Terelak, H.** 1998. Sulphur in soils of Poland – state and hazard. Bibl. Monit. Środ. (in Polish with English abstract).
17. **Nienartowicz, A., Piernik, A.** 2004.*1340 Śródlądowe słone łąki, pastwiska i szuwary (*Glauco-Puccinellietalia*, część – zbiorowiska śródlądowe). W: Herbich J. (ed.) Siedliska morskie i przybrzeżne, nadmorskie i śródlądowe solniska i wydmy. Poradniki ochrony siedlisk i gatunków Natura 2000 – podręcznik metodyczny. Ministerstwo Środowiska, Warszawa. T. 1, s. 97-119 (in Polish).
18. **Piernik, A.** 2003. Inland halophilous vegetation as indicator of soil salinity. Basic and Applied Ecology 4: 525-536.
19. **Pracz, J.** 1989. Properties of soils formed under the influence of saline ground water in the region of the Polish Baltic coast. Rozprawy naukowe i monografie. Wydaw. SGGW-AR, Warszawa (in Polish with English abstract).
20. **Pracz, J., Kwasowski, W.** 2001. Properties of sulphide soils in the Mrzeżyno zone. Roczn. Gleb. 52, 1/2: 39-50 (in Polish with English abstract).
21. **Pracz, J., Kwasowski, W.** 2001.Characterisrics of acid sulphate soils in the Mrzezyno zone. Roczn. Gleb. 52, 1/2: 23-37 (in Polish with English abstract).
22. **Revised Standard Soil Colour Charts**, 1992. Eijkelkamp Agrisearch Equipment.
23. **Systematics of Polish Soils.** 1989. Rocz. Glebozn. 40, 3/4 (in Polish with English abstract).
24. **van Reeuvijk, L.P.** 2002. Procedures for soil analysis. Sixth edition. ISRIC, Wageningen.

ТАКСОНОМІЧНЕ ПОЛОЖЕННЯ ЗАСОЛЕНИХ ҐРУНТІВ, ЩО МІСТЯТЬ ВІДНОВЛЕНІ ФОРМИ СУЛЬФУРУ

Гуліш П.[*], Пернік А.[**]

[*]*Кафедра грунтознавства, Інститут географії,*
[**]*Лабораторія екологічного моделювання, Інститут екології і захисту навколишнього середовища, Університет ім. М. Коперніка, Польща, hulisz@umk.pl*

Досліджувалися низовинні засолені ґрунти, які містять відновлені форми сульфуру. Таксономічна приналежність згідно класифікації WRB (2006) була визначена на основі головних властивостей ґрунту, засоленості і натрієвого статусу. Ці ґрунти близькі до потенційно кислих сульфатних ґрунтів. Також запропоновано модифікацію кваліфікаторів для реферативної грунтової групи (РГГ) солончаки.
Ключові слова: потенційно кислі сульфатні ґрунти, засолені ґрунти, potential acid sulphate soils, salt-affected soils, підкислення ґрунтів, сульфур, класифікація WRB.