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CHANGES OF REDOX PROPERTIES IN SLIGHTLY ERODED LOESS SOIL*

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A b s t r a c t: This paper presents results of changes of redox potential in loess soils along a slightly eroded slope situated in Motycz (Ciemięga river catchment near Lublin) in model conditions at full water saturation of soil at various temperatures (5, 10 and 20ºC).

K e y w o r d s: redox conditions, loess soil

INTRODUCTION

Soils developed from loess formations are among the most susceptible to the rate of redox potential (Eh) drop under anaerobic conditions [13,15] which is followed by the rapid reduction of the oxidized forms of their inorganic components. This concerns first of all biogenic elements such as nitrates and phosphates or heavy metals which, especially in eroded areas, migrate downhill and also to the water courses.

Investigation of soil redox conditions and their role in soil are very important for plants and are not yet enough recognized for environment quality as an indirect consequence of reduction processes [2-4,11,12,14,16].

The objective of the study was to determine Eh changes of the loess soil samples taken along the slightly eroded slope in laboratory at their full saturation conditions with water at various temperatures. The results concern a part of the

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wider investigations carried out in a small river Ciemięga catchment being under intensive agricultural use, characteristic for the loess areas of the Lublin Upland region [5,6,8-10]. The locality of soil sampling was Motycz and it was at the upper part of the catchment. Similar investigations were carried out in Baszki localized at the lower part of the catchment [7].

OBJECT AND METHOD OF THE STUDY

The object of the study was an eroded loess hill slope at the locality of Motycz near Lublin, situated in the upper part of the Ciemięga river catchment basin in the north-east part of the Nałęczów Plateau, a sub-region of the Lublin Upland [17].

The hill slope, with an angle of slope of about 2°, is covered with lessive and brown soils (tab. 1) with the granulometric composition of loamy silts. The content of C_{org} in the humus horizons varies from 1.74 to 5.42%, with the highest value in the lower part of the slope. The sub-humus horizons are characterized by much lower content of C_{org} (0.49 and 0.92%). The total specific surface area, characterizing jointly the granulometric composition and the humus content, indicates a certain differentiation – higher value (70.95 $m^2\ g^{-1}$) was in the soil at the lower part of the slope. In the soils of other locations they were in the range from 30.53 to 35.07 $m^2\ g^{-1}$. The values of the external specific surface area were in all soils in the narrow range from 6.39 to 10.26 $m^2\ g^{-1}$. The reaction of the soils studied is neutral, and even alkaline.

Table 1. Basic properties of soils

Location		Granulometric composition (% of fraction in mm)						$C_{org.}$	S H_2O	S N_2	pH H_2O
		1–0.1	0.1–0.05	0.05–0.02	0.02–0.005	0.005–0.002	<0.002	%	$m^2\ g^{-1}$	$m^2\ g^{-1}$	
1	A	27	12	35	13	3	10	1.74	35.07	7.06	6.6
	B	29	10	33	15	4	9	0.92	30.53	9.57	6.4
2	A	10	13	46	20	4	7	1.87	31.84	6.39	7.5
	B	7	11	47	21	10	4	0.49	31.12	10.26	7.8
3	A	8	12	48	20	7	5	5.42	70.95	8.63	7.4

Explanation: 1-3 – sampling position from the upper (1) to the lower (3) part of the slope. A – surface horizon, B – subsurface horizon

In 2003, soil samples for laboratory analyses were taken from three places on the slope studied (upper part – 1, middle part – 2 and lower part – 3) from the humus horizon (A, 0-20 cm in parts 1 and 3 and 0-10 cm in part 2) and the sub-humus horizon (B, 20-40 cm in part 1 and 10-20 cm in part 2). The soil samples were flooded with distilled water (at the ratio of 1:2.5) and incubated at 5, 10 and 20°C. In the course of the incubation, at different time intervals (60, 42 and 12 days) depending on the incubation temperature, Eh was measured in the soil suspension by means of PIONER.

Values obtained from the measurements (n = 20) permitted the determination of Eh dynamics in the course of the incubation process, and the determination of indexes indicating the limits below which manganese and iron oxides (index t_{300}) and nitrates (index t_{400}) are reduced [4].

Measurements of the basic properties of the soils were performed as follows: granulometric composition acc. to the areometric method, content of C_{org} acc. to Tiurin's method, total specific surface area (S H_20) acc. to the water vapour adsorption method, and the external specific surface area (S N_2) acc. to the nitrogen adsorption method.

RESULTS

Redox properties of soils are presented in Table 2 and in Figure 1. At the beginning of the incubation, Eh values in all 5 soil samples fell within the narrow range of 386-485 mV. Afterwards, the values decreased in the course of the incubation process, the rate and degree of the decrease being related to the incubation temperature and the place of sampling on the hill slope.

At 5°C (Fig. 1a), during the first 40 days of incubation, a systematic lowering in the Eh values (except some increase at the 30^{th} day) was observed in all the soil samples, with a highest difference (in comparison to the initial values of incubation) in the samples 1A (by 222 mV) and 3A (by 299 mV). A less pronounced lowering in the Eh value was found in the sample of soil 2A (by 164 mV) characteristic for the middle part of the slope, and in the samples of soil subsurface horizons 1B (by 147 mV) and 2B (by 122 mV).

During subsequent 20 days of continued incubation, the Eh values in most of the soil samples increased, reaching – on the 60^{th} day of the process – values from 200 to 300 mV, – values much lower than the initial ones (399-457 mV).

At the incubation temperature of 10°C (Fig. 1b), the course of changes in the Eh of the soils during the 42 days of incubation was similar to that at 5°C with the same tendency in sample situation on the graph.

At 20°C (Fig. 1c), the course of the redox processes during the incubation of the soils studied was the fastest (till day 12) when compared to the changes occurring at 10 and 5°C. The Eh values at the end of the incubation were from 100 to 255 mV in comparison to the initial values equal from 386 to 485 mV. The courses of the curves of the changes were gentle, and the differences among the particular samples were the smallest, except for sample 3A which in all temperatures changes were more rapid. Deeper horizons (B) proved to be more resistant to Eh changes than upper (A) horizons.

Table 2. Changes of Eh (mV) during the incubation of soil samples at different temperatures

Location		Day of incubation at 5ºC							Mean
		1	10	20	30	40	50	60	
1	A	440	344	316	315	218	240	253	304
	B	457	423	390	448	310	343	303	342
2	A	414	380	323	419	250	290	234	330
	B	399	375	336	422	277	266	301	339
3	A	414	279	234	220	115	152	209	232
Mean	A	423	334	291	318	194	227	232	288
	B	428	399	363	435	293	304	302	361

Location		Day of incubation at 10ºC							Mean
		1	7	14	21	28	35	42	
1	A	440	433	283	286	245	250	217	308
	B	457	434	352	381	371	379	325	432
2	A	414	357	270	276	295	277	260	344
	B	399	325	284	251	295	253	231	324
3	A	414	372	170	105	181	100	131	229
Mean	A	423	387	241	222	240	209	203	275
	B	428	379	318	316	333	316	278	338

Location		Day of incubation at 20ºC						Mean
		0.125	1	2	4	9	12	
1	A	386	320	338	306	188	191	320
	B	485	391	373	355	220	212	375
2	A	405	309	345	272	231	214	332
	B	391	296	333	310	255	255	349
3	A	423	248	184	126	96	100	213
Mean	A	405	292	289	235	163	168	423
	B	438	343	353	332	237	233	323

Expl.: 1-3 sampling position from the upper (1) to the lower (3) part of the slope A – surface horizon, B – subsurface horizon

Table 3. Eh (mV) at the 7th, 10th and 12th day of incubation

t (°C)	A		B	
5	1	344	1	423
	2	380	2	375
	3	279		
10	1	433	1	434
	2	357	2	325
	3	372		
20	1	191	1	212
	2	214	2	255
	3	100		
Mean	1	323	1	356
	2	317	2	318
	3	250		

Table 4. Soil aeration indicators (days) at different temperatures

Location		5°C		10°C		20°C	
		t_{300}	t_{400}	t_{300}	t_{400}	t_{300}	t_{400}
1	A	31.5	4	13	8.5	4	0.1
1	B	> 60	17	60	10	6	1
2	A	37	4	11.5	2.5	3	0.125
2	B	38.5	0.125	9.5	1	1	0.1
3	A	8.5	1	9.5	3.5	1.75	0.25

In the characteristic days of incubation, the 7th, 10th and 12th, which were comparable for the courses of all the incubation temperatures, both the surface horizons (A) and the deeper horizons (B) differed less with respect to the Eh values at the lower temperatures of 5 and 10°C than during longer time of incubation (Tab. 3).

There is a noticeable overall tendency for Eh to decrease in the soils from the upper towards the lower parts of the hill slope.

Soil aeration indicators t_{300} and t_{400} showed a great differentiation depending on the temperature and also between soil samples localization on the slope and along the catchment (Tab. 4). Values of t_{300} varied from 1 to more than 60 days and those of t_{400} were from 0.125 to 17 days. Soil sample 1B showed the highest values of both indicators in all temperatures.

In all temperatures t_{300} values were higher than t_{400} for all soil samples and they decreased with an increase of temperature and reached below 1 day at 20°C. Only some abnormal twofold higher values *of* t_{400} were found at 10°C in comparison to those at 5°C.

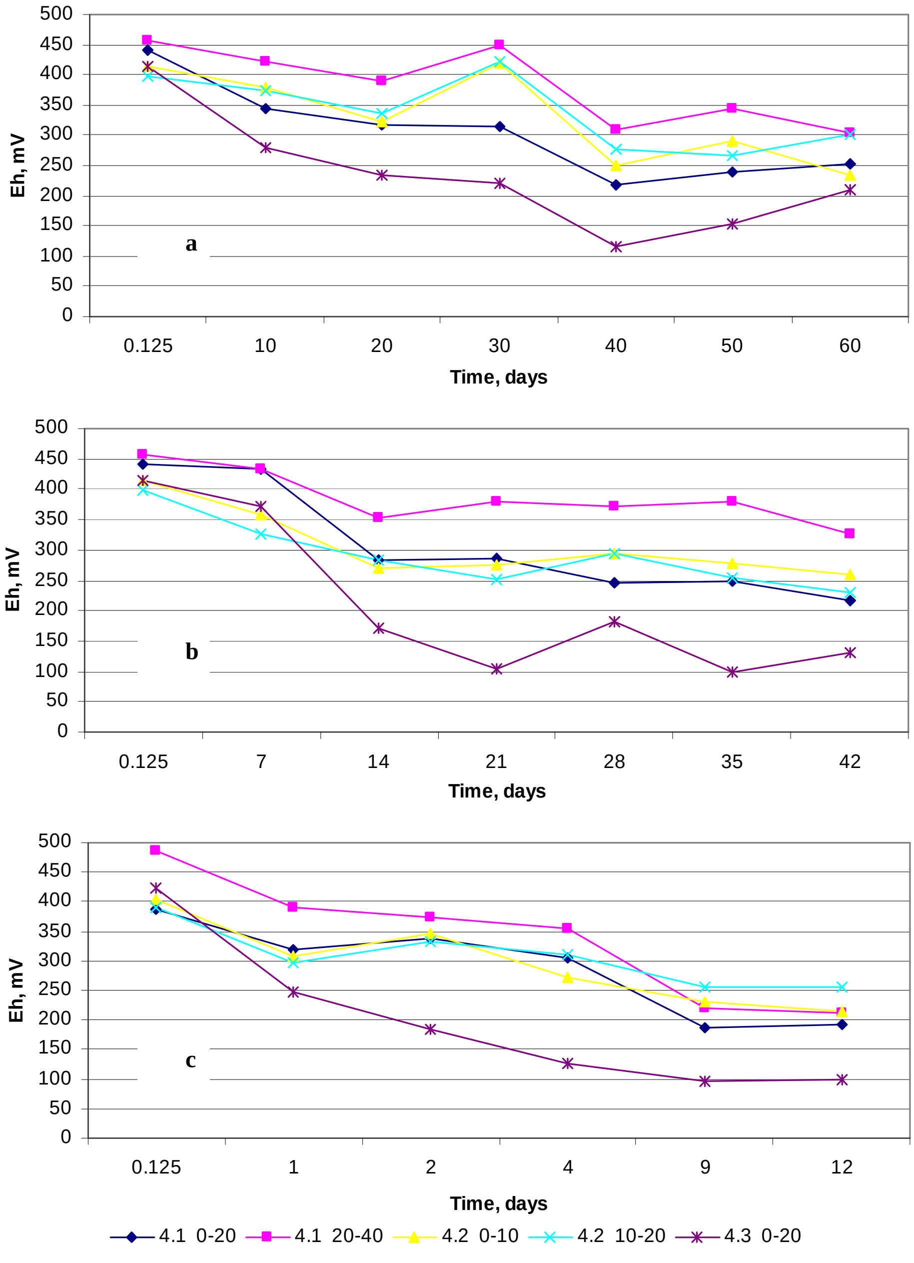

Fig. 1. Eh changes during the incubation of soil samples at (a) 5, (b)10 and (c) 20°C

CONCLUSIONS

1. Under full saturation conditions, the soils formed from loess at the Motycz locality reached the lowest Eh values on the 40^{th} day of incubation at 5°C, on the 21^{st} day of incubation at 10°C, and on the 12^{th} day of incubation at 20°C in comparison to the initial values.

2. The soil situated on the lower parts of the hill slope proved to be more susceptible to changes in Eh value, while those from the upper part of the slope were the most resistant. Also more resistant occurred to be soil samples from the lower horizons than those of the upper ones.

3. The resistance of soils to reduction at 20°C, as expressed by the t_{300} and t_{400} indexes, is several days and less than a day, respectively.

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ZMIANY WŁAŚCIWOŚCI OKSYDOREDUKCYJNYCH W SŁABO ERODOWANEJ GLEBIE LESSOWEJ

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S t r e s z c z e n i e. Praca zawiera wyniki dotyczące zmian potencjału redoks w glebach lessowych wzdłuż słabo erodowanego zbocza usytuowanego w Motyczu (zlewnia rzeki Ciemięgi w pobliżu Lublina) uzyskane w warunkach modelowych przy pełnym nasyceniu gleby wodą i w różnych temperaturach (5, 10 i 20^{o}C).

S ł o w a k l u c z o w e: stosunki oksydoredukcyjne, gleby lessowe