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CHARACTERISTICS OF SOILS SUBJECTED TO FLOOD IN JULY 1997 AT THE REGION OF LUBSZA COMMUNITY - SITUATION AFTER 5 MONTHS

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A b s t r a c t. Soils waterlogged for a period of about 30 days during the great flood in Poland in July 1997 were examined for total carbon, nitrogen and sulphur, heavy metal concentration, sorption properties and salinity. The aim of the investigation was to characterise the flooded arable soils 5 months after the flood, and to compare the properties of cultivated soils with non-ploughed soils. The investigation revealed that the flood influenced soil properties mainly by depositing a thin layer of sediment containing organic matter and some heavy metals, especially zinc. Five months after the water subsided from the studied area, there were still some non-cultivated fields where the layer of the sediment was recognisable and possible to collect. Zinc concentrations in the surface (0- 20 cm) layer of several non-cultivated soils were higher than the concentrations in cultivated soils, indicating that the flood influenced soil properties. However, the heavy metal contents in soils after the flood did not exceed the natural background. Soils subjected to the flood are characterised by a high saturation of sodium, which could be still observed 5 months after the flood. Despite the high saturation of sodium, investigated soils did not indicate excess salinity.

K e y w o r d s: flood, overflowed soils, soil properties, heavy metals

INTRODUCTION

Flooding is a natural phenomenon occurring often in different parts of Poland. To prevent floodplain areas against overflow, a system of dams and water reservoirs was built up, and a line of anti-flood banks was established along main rivers. However, all these arrangements were insufficient to contain river water when the great flood of July 1997 embraced southern and western part of Poland. Huge masses of water from the river Oder catchment breached anti-flood banks in several places and many rural and urban areas, including the big cities of Opole and Wroclaw, were flooded for different period and to a different extend. The rural area of Lubsza was severely hit by the flood with 7 089 hectares of arable land covered by water for a very long time. Consequently, crops were damaged, and when the water finally subsided much arable land was left without cultivation.

The aim of the investigation was to define the characteristics of flooded soils 5 months after the flood, and to compare the properties of non-cultivated soils (arable soils left after the flood subsided) with those cultivated after the flood (ploughed soils without vegetation or covered by rising plants).

MATERIALS AND METHODS

Soils under the investigation were located in an area waterlogged during the flood for a period of about 30 days. Five objects were chosen for detailed study (Table 1), each consisted of cultivated (marked in tables as "C") and non-cultivated (marked in tables as "N")

Table 1. General information on subjects under the investigation

Object No. and location	Soil No.	Status of the soil in December '97	Textural class (Polish)	Textural class (U.S.D.A.)
I. Czepielowice 1	I. N	arable soil allowed after the flood to rest	pl	sand
	I. C	ploughed arable soil without vegetation	pl	sand
II. Nowe Kolnie 1	II. N	arable soil allowed after the flood to rest	ps	sand
	II. C	ploughed arable soil without vegetation	ps	sand
III. Czepielowice 2	III. S	sediment	glp	sandy loam
	III. N	arable soil left with demaged rye	pgl	loamy sand
	III. C1	ploughed arable soil with rising plants	pgl	loamy sand
	III. C 2	ploughed arable soil without vegetation	pgl	loamy sand
IV. Kościerzyce	IV. S	sediment	pli	silty loam
	IV. N	arable soil allowed after the flood to rest	gśp	loam
	IV. C	ploughed arable soil with rising plants	gśp	loam

soils, located very close each other. There were two different categories of cultivated soils in object III depending on plant cover during sampling: III.C1 - ploughed arable soil with rising plants, and III.C2 - ploughed arable soil without any vegetation. Soil material from the top (0-20 cm) and a deeper layer (25 - 40 cm) were sampled. The sediments (marked in tables as "S") varying in thickness from about 3 to 5 mm and deposited by flood water, were collected from the surface of soils in objects III and IV, as well.

In the soil and sediment samples the following properties were determined:
- soil texture by Bouyoucose's areometric method, modified by Cassagarande and Proszynski;
- pH in water and 1.0 M KCl by potentiometric method;
- total carbon and sulphur contents by CS-MAT 550 analyser at temp. 1200°C;
- total nitrogen content by Kjeldahl's method;
- total content of Cu, Zn, Pb, Cr, Cd, Ni, Mn and Fe extracted with $HClO_4$, as determined by AAS Philips spectrometer;
- hydrolitic acidity (Hh) in 1.0 M CH_3COOCa by Kappen's method;
- Na, K, Mg and Ca exchangeable cations in 1.0 N NH_4Cl by Pallman's method;
- sum of bases (S) was calculated by Pallman's method of exchangeable cations;
- cation exchangeable capacity (CEC) was calculated as the sum of hydrolitic acidity and exchangeable cations;
- saturation with bases (V) and exchangeable cations were calculated as percent of bases and particular cations in CEC, respectively;
- salinity by the conductometric method and calculated as mg KCl in 1.0 kg of soil.

RESULTS

The most important environmental problems connected with flood are damage to trees [6]. Arable soils, to a less extent, are affected in three primary ways: 1) physical removal of surface soil and the deposit of barren sandy material; 2) changes of soil properties as a result of long water saturation and poor aeration; and, 3) modification of soil properties by the ions and suspensions of the flood water. In this paper the flood effect on soil physico-chemical and chemical properties was studied. Since soil tolerance to chemical influence depends mainly on soil colloids content, objects of different texture were selected for investigation (Table 2).

The examined soils represented textural classes from sand (object I and object II), through loamy sand (object III) to loam (object IV). Although soils of both, object I and object II, belong to the sand textural class, they differ each other. The latter one contains slightly more clay fraction, and according to Polish classification belongs to another textural class.

The granulometric composition of the sediment deposited on the surface of the soil is correlated with the flow rate of flood water. If there were no obstacles in the way, the rate was higher and sediment contains more coarse fraction. This situation occured in object III, located in an open area, where sediment indicated composition of sandy loam (Table 2). Object IV was located close to a forest, where the water flow rate was lower and consequently the sediment is characterised by silty loam texture.

The general properties of soils under the investigation are shown in Table 3. They indicate a different reaction, depending on the soil texture. Sandy soils are characterised by acid reaction, while soils derived from loam indicated neutral reaction. The carbon and nitrogen content in the examined soils were typical for arable soils of Poland. All soils and sediments are characterised by a low concentration of sulphur [4], whose content - the same as carbon and nitrogen - did not depend on the post-flood cultivation status. Organic matter transformation processes are connected with the aeration and soil reaction. Sandy soils are characterised by stronger mineralization and thus generally show a lower content of carbon and nitrogen than the loamy soils. Bigger amounts of carbon, nitrogen and sulphur determined in surface layer are connected with higher contents of organic matter present in the soil material.

The sediment has a different reaction, correlated with the reaction of the soil, where it was collected. This is probably a result of the interaction between the soil and the sediment which took place during 5 months after the flood water subsided. The sediment was reach in organic components and indicated relatively high content of carbon and nitrogen, and contained higher amounts of sulphur, as well.

Bottom sediments and materials carried by the river are usually characterised by a high content of heavy metals [5]. The chemical composition of the sediment deposited on the studied area indicated that it contains not very high concentrations of heavy metals (Table 4). However, the sediment was collected 5 months after the flood, and the chemical composition of the sediment can differ from the sediment composition determined directly after the deposition. Zinc was the only element occurring in high amounts and its concentration reached nearly 500 mg kg^{-1}. This element is easily removed from the soil and its high concentrations are typical for bottom sediments [1].

To define precisely to what extent the flood influenced the concentration of heavy metals in the soils, examination of much bigger number of samples collected before and after waterlogging is necessary. In spite of that, investigations clearly show, that heavy metal contents in soils under investigation do not exceed values usually occurring in arable soils [2]. The sediment deposited from flood water was very thin, and heavy metal concentrations in the soil have not been strongly affected. Although flood sediment was rich in zinc, only soils in object IV indicated enrichment (but not contamination) by this element. Usually zinc concentration in surface soil is higher than in subsoil, because of higher content of humus and sorption capacity. However, there are differences in zinc concentration when comparing surface and deeper layers of cultivated and non-cultivated soils. With the exception of object III, the surface layers of soils after flooding indicated much higher concentrations than those being ploughed. Furthermore, the difference of zinc concentration in surface and deeper layers are more distinctive in non-cultivated soils than in cultivated soils. This indicated that flood action enriches surface soils with zinc, and that the concentration of this element had been decreased as a result of ploughing, and mixing the surface material with deeper layers.

The sorption properties of the studied soils indicated a very high content of exchangeable sodium (Table 5). The saturation of sorption complex with sodium is even higher than those of magnesium and potassium (Table 6). There is no doubt that this is a consequence of saturation during waterlogging, and even a period of 5 months was not enough to return to the natural

Table 2. Soil texture

Object No. and location	Soil No.	Depth (cm)	Percent of fraction						
			> 2000	According to U.S.D.A. (μm)			According to Polish PTG (mm)		
				2000-50	50-2	<2	1-0.1	0.1-0.02	<0.02
I. Czępielowice 1	I. N	0 - 20	0.6	94	5	1	90	5	5
		25 - 40	0.5	96	3	1	93	4	3
	I. C	0 - 20	0.3	92	7	1	88	7	5
		25 - 40	0.1	94	5	1	84	11	5
II. Nowe Kolnie 1	II. N	0 - 20	2.0	89	9	2	82	11	7
		25 - 40	1.0	89	7	4	82	9	9
	II. C	0 - 20	2.3	89	10	1	83	10	7
		25 - 40	0.6	90	8	2	84	8	8
III. Czępielowice 2	III. S	0 - 0.5	0.0	59	28	13	46	30	24
	III. N	0 - 20	1.2	77	16	7	69	18	13
		25 - 40	1.1	77	17	6	70	17	13
	III. C1	0 - 20	0.7	79	14	7	72	15	13
		25 - 40	3.7	84	10	6	78	11	11
	III. C2	0 - 20	0.5	78	15	7	65	22	13
		25 - 40	0.3	71	19	10	60	23	15
IV. Kościerzyce	IV. S	0 - 0.5	0.0	29	57	14	17	47	36
	IV. N	0 - 20	0.9	36	40	24	29	26	45
		25 - 40	0.6	31	38	31	24	27	49
	IV. C	0 - 20	0.7	41	35	24	31	30	39
		25 - 40	0.0	37	40	23	29	34	37

Table 3. Content of total forms of: carbon, nitrogen and sulphur, C/N ratio, and pH

Object No. and location	Soil No.	Depth (cm)	pH		C (%)	N (%)	C/N	S (mg 100 g^{-1})
			H_2O	KCl				
I. Czepielowice 1	I.N	0 - 20	5.50	4.50	0.629	0.043	14.6	11.7
		25 - 40	5.20	4.65	0.056	0.009	6.2	5.1
	I.C	0 - 20	4.90	4.35	0.648	0.056	11.5	15.2
		25 - 40	4.90	4.40	0.097	0.014	6.9	6.7
II. Nowe Kolnie 1	II.N	0 - 20	6.00	5.10	0.824	0.063	13.1	16.5
		25 - 40	6.00	5.10	0.294	0.044	6.7	6.5
	II.C	0 - 20	6.10	5.90	0.933	0.063	14.8	11.6
		25 - 40	6.20	5.50	0.256	0.014	18.3	7.2
III. Czepielowice 2	III. S	0 - 0.5	5.10	4.40	2.463	0.152	16.2	62.2
	III. N	0 - 20	5.10	4.40	0.800	0.089	9.0	18.3
		25 - 40	6.40	5.50	0.146	0.011	13.2	5.4
	III. C1	0 - 20	5.50	4.50	0.872	0.153	5.7	15.4
		25 - 40	6.10	5.20	0.067	0.009	7.4	4.5
	III. C2	0 - 20	5.50	4.50	0.786	0.059	13.3	14.1
		25 - 40	6.20	5.20	0.180	0.007	25.7	6.1
IV. Kościerzyce	IV. S	0 - 0.5	7.40	5.70	3.037	0.205	14.8	81.5
	IV. N	0 - 20	7.50	6.70	1.529	0.154	9.9	10.6
		25 - 40	7.50	6.75	0.893	0.062	14.4	10.6
	IV. C	0 - 20	7.30	6.70	1.324	0.106	12.5	11.5
		25 - 40	7.50	6.40	0.488	0.058	8.4	12.5

Table 4. Total concentration of heavy metals

Object No. and location	Soil No.	Depth (cm)	Cu	Zn	Pb	Cr	Cd	Ni	Mn	Fe
						(mg kg^{-1})				(%)
I. Czepielowice 1	I. N	0 - 20	5.5	54.0	13.5	2.5	0.67	9.0	130.5	0.29
		25 - 40	3.5	12.5	4.0	4.5	0.58	14.5	48.0	0.19
	I.C	0 - 20	4.0	28.0	12.0	3.5	0.42	3.0	128.5	0.32
		25 - 40	5.5	18.0	2.0	2.5	0.67	2.0	411.0	0.54
II. Nowe Kolnie 1	II. N	0 - 20	6.5	46.5	19.0	4.5	0.42	3.5	224.0	0.41
		25 - 40	5.0	20.5	9.0	4.0	0.50	1.5	204.0	0.52
	II. C	0 - 20	2.5	25.5	4.0	1.5	0.42	6.0	104.5	0.20
		25 - 40	3.5	16.5	8.5	2.0	0.58	5.5	154.5	0.34
III. Czepielowice 2	III. S	0 - 0.5	17.0	119.0	34.5	10.5	0.42	3.5	654.0	1.64
	III. N	0 - 20	7.5	43.0	13.5	5.5	0.50	2.0	363.0	0.71
		25 - 40	5.0	20.5	4.0	4.0	0.58	4.0	165.0	0.51
	III. C1	0 - 20	7.5	39.0	18.0	5.0	0.67	4.0	284.0	0.55
		25 - 40	3.5	19.0	traces	9.0	0.67	2.0	54.5	0.18
	III. C2	0 - 20	8.0	41.5	16.5	6.0	0.50	8.0	373.0	0.64
		25 - 40	8.5	30.5	8.5	5.5	0.42	6.5	278.0	0.87
IV. Kościerzyce	IV. S	0 - 0.5	42.5	499.0	49.5	16.0	1.00	36.5	57.5	3.47
	IV. N	0 - 20	27.0	266.0	30.5	10.5	1.00	29.5	36.5	2.65
		25 - 40	21.5	126.5	30.5	12.5	0.83	34.5	47.0	3.19
	IV. C	0 - 20	18.5	100.2	31.5	12.0	0.67	28.5	525.0	2.61
		25 - 40	22.0	94.5	30.0	11.5	0.83	37.0	975.0	4.11

Table 5. Sorption properties

Object No. and location	Soil No.	Depth (cm)	H^+	Ca^{++}	Mg^{++}	K^+	Na^+	S	CEC	V
			cmol (+) kg^{-1}							(%)
I. Czepielowice 1	I. N	0 - 20	2.88	1.56	0.08	0.13	0.37	2.14	5.02	42.6
		25 - 40	1.23	1.48	0.04	0.05	0.38	1.95	3.18	61.3
	I. C	0 - 20	3.43	1.48	0.02	0.17	0.41	2.08	5.51	37.7
		25 - 40	1.81	1.73	0.01	0.07	0.38	2.19	4.00	54.8
II. Nowe Kolnie 1	II. N	0 - 20	1.47	2.66	0.23	0.12	0.40	3.41	4.88	69.9
		25 - 40	1.54	2.70	0.17	0.14	0.39	3.40	4.94	68.8
	II. C	0 - 20	1.51	3.68	0.57	0.30	0.41	4.96	6.47	76.7
		25 - 40	1.06	2.70	0.11	0.24	0.38	3.43	4.49	76.4
III. Czepielowice 2	III. S	0 - 0.5	7.35	4.93	0.55	0.53	0.82	6.83	14.18	48.2
	III. N	0 - 20	3.98	1.98	0.04	0.28	0.41	2.71	6.69	40.5
		25 - 40	0.72	3.19	0.07	0.12	0.41	3.79	4.51	84.0
	III. C1	0 - 20	3.52	1.97	0.01	0.22	0.39	2.59	6.11	42.4
		25 - 40	0.51	2.22	0.11	0.14	0.41	2.88	3.39	85.0
	III. C2	0 - 20	3.52	1.98	0.01	0.29	0.41	2.69	6.21	43.3
		25 - 40	1.17	3.68	0.19	0.17	0.43	4.47	5.64	79.3
IV. Kościerzyce	IV. S	0 - 0.5	0.88	13.29	1.62	0.80	0.90	16.61	17.49	95.0
	IV. N	0 - 20	0.76	14.73	1.59	0.97	1.04	18.33	19.09	96.0
		25 - 40	0.66	19.12	1.66	0.53	1.13	22.44	23.10	97.1
	IV. C	0 - 20	1.09	15.73	1.44	0.72	0.82	18.71	19.79	94.5
		25 - 40	4.63	22.40	1.38	0.44	1.13	25.35	29.98	84.6

Table 6. Sorption complex saturation with exchangeable cations and salinity

Object No. and location	Soil No.	Depth (cm)	H^+	Ca^{++}	Mg^{++}	K^+	Na^+	Salinity (mg KCl kg^{-1})
					(%)			
I. Czepielowice 1	I. N	0 - 20	57.4	31.3	1.6	2.6	7.3	273
		25 - 40	38.7	46.5	1.2	1.6	11.9	86
	I. C	0 - 20	62.2	26.9	0.4	3.1	7.4	187
		25 - 40	45.2	43.3	0.3	1.8	9.5	172
II. Nowe Kolnie 1	II. N	0 - 20	30.1	54.5	4.7	2.5	8.2	72
		25 - 40	31.2	54.7	3.4	2.8	7.9	86
	II. C	0 - 20	23.3	56.9	8.8	4.6	6.3	143
		25 - 40	23.6	60.1	2.4	5.3	8.5	158
III. Czepielowice 2	III. S	0 - 0.5	51.8	34.8	3.9	3.7	5.8	589
	III. N	0 - 20	59.5	29.6	0.6	4.2	6.1	187
		25 - 40	16.0	70.7	1.6	2.7	9.1	72
	III. C 1	0 - 20	57.6	32.2	0.2	3.6	6.4	72
		25 - 40	15.0	65.5	3.2	4.1	12.1	77
	III. C 2	0 - 20	56.7	31.9	0.2	4.7	6.6	86
		25 - 40	20.7	65.2	3.4	3.0	7.6	158
IV. Kościerzyce	IV. S	0 - 0.5	5.0	76.0	9.3	4.6	5.1	790
	IV. N	0 - 20	4.0	77.2	8.3	5.1	5.4	574
		25 - 40	2.9	82.8	7.2	2.3	4.9	589
	IV. C	0 - 20	5.5	79.5	7.2	3.6	4.1	503
		25 - 40	15.4	74.7	4.6	1.5	3.8	402

situation. Although soils subjected to flood are characterised by high saturation with sodium, they do not indicated high salinity. Obtained results, including the sediment, are much lower than 1 500 mg KCl kg^{-1}, assumed as limit values for soil salinity [3].

CONCLUSIONS

1. The investigation pointed out that the flood influenced soil properties mainly by deposition of thin layer of sediment rich in organic matter and some heavy metals, especially zinc. Five months after the water flowed out from the field under study, there were still some non-cultivated fields where the layer of the sediment was recognisable and possible to collect.

2. Zinc concentrations in surface (0 - 20 cm) layer of several non-cultivated soils were higher than those in cultivated soils, indicating that the flood influenced soil properties. However, the heavy metal content in soils after the flood do not exceed the natural background.

3. Soils subjected to waterlogging are characterised by high saturation with sodium, which could still be observed 5 months after the flood. Despite the high saturation with sodium, investigated soils do not indicate excess salinity.

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