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EFFECT OF SOIL INUNDATION ON ITS PROPERTIES IN THE REGION OF ŚWIECKO DURING SUMMER FLOODING

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A b s t r a c t. The present experiments were carried out on the soils of the Rybocice polder near Świecko, which was purposefully flooded with waters of the Odra river during the summer flood of 1997 that caused complete destruction of crops and meadow sward. The flooded areas remained under water for more than 30 days. The dominant soils found in this area are river alluvial soils (Fluvisols) of varying texture. Because of their location and poorly operating drainage system, the discussed soils are periodically too wet by nature or water-logged. In the spring (March/April) of 1998 the ground water table occurred at the depth of 30 cm on damaged grasslands and at 90 cm on some arable fields. The content of organic carbon ranged from 0.7 to 3.2% in horizon A with depth of approximately 30 cm. Soil reaction was found to vary considerably - from pH (KCl) 4.2 to pH 7.6. Long purposeful inundation with flood waters was not found to have caused significant negative effects on chemical properties of the examined soils. No noticeable contamination with heavy metals (Pb, Cu, Zn, Cd, Cr and Mn) or policyclic aromatic hydrocarbons (PAH) was observed. Bulk density in this region, without any treatment from the period of flooding to the spring of 1998 was approximately 1.60 Mg/m^3 as compared with 1.40 Mg/m^3 on the field cultivated (ploughed) in spring and sown with spring cereal. The mean crop yield in 1998, when appropriate agro-techniques were applied, did not vary significantly from the long-term averages.

K e y w o r d s: Fluvisols, disaster flood, heavy metals, PAH

INTRODUCTION

During the disaster summer flood of 1997, a lot of agricultural lands were, for some time, covered with water of unknown chemical and physical properties. Such a situation took place in the area of the Rybocice polder near Świecko which was purposefully inundated with waters of the Odra river. Configuration of the terrain - between embankments of the Odra and Ilanka rivers - made flood waters exceed 3 m in places. The flooded areas remained under water for more than 30 days, causing complete destruction of crops and meadow sward.

There was also an impact of long-term soil submergance on different soil properties. In such conditions, microbiological processes in the soils can change abruptly from aerobic to anaerobic conditions. Flooding water can influence both physical and chemical properties of the soils, especially on the surface layers.

One of the most important impacts of the flooding water on agricultural land is soil pollution by some chemical compounds dissolved in inundated water. Among the most dangerous contaminants there are heavy metals and some policyclic aromatic hydrocarbons [6].

Very few papers [5] concern the impact of disaster flooding during the summer of 1997 on the soil cover.

Here we describe investigations on different soil properties a few months after the flooding water had disappeared from the inundated land of the Rybocice polder near Świecko and crop conditions in the summer of 1998 (a year after flooding).

MATERIAL AND METHODS

The study area, polder of Rybocice near Świecko (Fig. 1), is located between the embankments of the Odra and Ilanka rivers. In this area, river alluvial soils dominate (acc. to FAO classification - Fluvisols [1]). The investigated soils have developed from alluvial deposited materials with varying texture into a spatial and vertical pattern. Because of their location system and poorly operated drainage system, they are medium or strongly gleyed. From the investigated area, 18 composite samples were taken from the surface layer of particular arable fields or grassland. Some investigations on the deeper layers were also carried out. The investigation area was about 50 ha.

Fig. 1. Location of investigated area.

All composite soil samples taken from the examined area were air-dried, and than sieved through a 2 mm sieve.

In fine earth materials (2 mm) the following analysis were done:

(1) particle-size distribution - by the hydrometer method acc. to Prószyński, using as dispersing agent "Calgon" [2],
(2) pH - in 1M KCl by pH-meter,
(3) organic carbon (C org.) - by the Turin's method [2],
(4) forms of potassium and phosphorus available for plants by the Egner-Rhiem's (DL) method [2],
(5) available magnesium by Schachtschabel's extraction using an AAS apparatus [2],
(6) heavy metals - (Zn, Pb, Cr, Cu, Cd and Mn) - after soil digestion with HF and $HClO_4$, and residues-dissolved with HCl. The atomic absorption technique (AAS) was used for the determination of heavy metals content,
(7) policyclic aromatic hydrocarbons (PAH) were determined in fresh soil sample by the two dimensional thin-layer chromatographic method acc. to Polish Standard [3].

In some of the tested areas, physical measurement were done:

- depth of the ground water table - by soil borer,
- bulk density - by sampling of undisturbed sample to metal cylinders (V=100 cm^3) and over-drying methods,
- soil structure - by macroscopic observation.

The plant yield in 1998 (i.e. 1 year after flooding) was observed by field inspection during harvesting (July), recorded on photos, and estimated.

RESULTS

The soils on the Rybocice polder near Świecko are characterised by varying texture of surface layers. Clay content of these layers ranged from 3 to 30%, but the content of silt fractions from 18 to 46% (Table 1).

Soil reaction varied considerably - from $pH_{(KCl)}$ 4.2 to pH 7.6, similarly to macro nutrient availability of the soil, mainly availabiltiy of phosphorus and potassium (2nd-5nd class of nutrient availability acc. to the classification used in Poland [2]). Content of available magnesium forms was in most cases - high (Table 2). Humus content ranged from about 1.5% to near 6% (0.76-3.24 % of organic carbon) but the average thickness of the A horizons was about 30 cm. The highest total content among heavy metals was found for manganese (180-790 mg/kg), chromium (41-100 mg/kg) and zinc (24-78 mg/kg). The content of lead and cooper ranged, alternatively, from 15 to 52 mg/kg and 8 to 21 mg/kg, but a very low content of cadmium was found in all the investigated samples <0.1 mg/kg (Table 3). None of the heavy metals was found in the concentration above the allowable limit (Table 4).

Table 1. Particle-size distribution (in % w/w)

Sample No.	Fraction diameter in mm			
	Sand 2-0.05	Silt 0.05-0.002	Clay <0.002	Textural group acc. to PN-R-04033
1	72	21	7	sandy loam
2	57	24	19	light loam
3	64	23	13	light loam
4	42	46	12	sandy silt
5	51	42	7	sandy loam
6	52	33	15	light loam
7	32	42	30	light loam
8	61	26	13	light loam
9	66	26	8	light loam
10	61	29	10	loamy sand
11	78	19	3	loamy sand
12	74	22	4	loamy sand
13	77	20	3	loamy sand
14	78	18	4	loamy sand
15	74	21	5	loamy sand
16	63	27	10	light loam
17	44	45	11	loam
18	57	35	8	light loam

Similarly, very low concentration of six analysed policyclic aromatic hydrocarbons (PAH - Table 4) were found. Sum of all the analysed PAH varied from less than 2 to 4.6 μg/kg.

The some soil physical measurements taken in the spring (March/April) of 1998 show the ground water table at the depth of about 30 cm on damaged grasslands, and at about 90 cm on arable fields.

Surface layers observed on some of the fields showed relatively good aggregation of soil mass, and small compaction. It was partly confirmed by the measurements of bulk density. For example, bulk density in the field without any treatment from the period of flooding to the spring of 1998 was approximately 1.60 Mg/m^3, but in the field cultivated in spring and sown with spring cereal - 1.40 Mg/m^3 (Table 6).

DISCUSSION

Long (30 days) inundation with flooding waters in 1997 on the alluvial soil on the Rybocice polder near Świecko, did not cause any significant negative effects on the chemical and physical properties of the examined soils. No noticeable contamination with heavy metals (Pb, Cu, Zn, Cd, Cr and Mn) and policyclic aromatic hydrocarbons (PAH) was observed. Possible changes in other

Table 2. Soil chemical properties

Sample No.	pH in KCl	C org. %	P_2O_5 mg/100 g	K_2O mg/100 g	Mg mg/100 g
1	7.6	0.94	14.8	19.4	10.9
2	5.0	1.48	5.6	11.2	13.7
3	5.1	1.50	4.4	8.3	12.9
4	5.2	2.96	2.8	7.6	20.5
5	5.4	3.13	2.0	9.9	21.2
6	6.0	1.80	7.4	8.2	11.6
7	5.6	1.13	2.0	10.7	15.3
8	7.0	0.97	13.2	9.6	10.6
9	6.3	0.82	14.0	19.8	11.9
10	7.5	1.84	8.6	23.5	16.6
11	7.5	1.14	8.3	13.6	12.1
12	7.5	1.21	9.4	12.2	14.4
13	7.6	1.05	11.3	27.6	13.0
14	7.6	0.76	7.6	16.5	8.7
15	7.5	1.26	10.0	15.8	11.3
16	7.3	1.67	1.7	17.7	10.0
17	5.8	3.24	3.0	10.2	22.4
18	7.4	1.62	3.8	10.5	15.1

Table 3. Content of heavy metal in soil surface layer (in mg/kg)

Sample No.	mg/kg					
	Zn	Pb	Cr	Cu	Cd	Mn
1	23.5	17.6	50.5	9.7	<0.1	232.7
2	36.8	27.6	59.7	13.7	in all	548.2
3	69.6	52.1	74.5	20.5	samples	750.7
4	54.8	42.1	71.5	20.1		604.2
5	40.1	30.0	62.5	16.3		725.2
6	78.1	46.4	100.7	17.4		648.2
7	42.6	28.2	58.2	11.4		320.2
8	49.7	30.7	46.7	10.4		304.5
9	32.1	25.1	56.2	15.2		310.7
10	22.6	17.2	41.5	10.7		227.5
11	27.8	21.0	43.2	10.9		178.0
12	28.1	15.2	51.2	11.1		237.0
13	22.1	16.2	47.5	7.9		274.7
14	27.2	19.6	48.5	8.7		246.7
15	26.7	18.2	71.0	15.9		420.7
16	49.8	35.0	68.2	20.5		787.0
17	33.3	24.4	65.0	10.7		460.2

Table 4. Allowable content of heavy metals in arable soils (in mg/kg)

Element	Coarse-textured soils	Fine-textured soils
Zn	200	300
Pb	50	100
Cu	50	100
Cd	3	3
Cr	100	300
Mn	-	-

basic chemical properties of these soils such as pH, macro-nutrient availability or the content of humus compounds were so small that it was not possible to determine their significance unequivocally. One of the possible explanations of such minute changes is poor internal drainage in these soils (strong gleying); that explains why the majority of waters from flooded fields ran off to the rivers by ditches (after flood waters had receded) and did not filter through the soil profile. Deterioration of the structure ("dilution" of aggregates) and, consequently, changes in the bulk density (and compaction of soil mass) were also hardly noticeable. Relatively slight alterations in the degradation of structural properties resulted from the "protective role" of the plant cover which constituted a kind of soil mulch. These relatively small negative influence of the summer flood of 1997 on soil properties in the examined region was confirmed "indirectly" by the crop yields in 1998. When appropriate agrotechnical practices were

Table 5. Content of policyclic aromatic hydrocarbons (PAH) (in µg/kg)

Sample No.	Fluoranten	Benzo(a) -piren	Benzo(b) -fluoranten	Benzo(k) -fluoranten	Indeno (1,2,3-c,d) piren	Benzo(ghi) -perylen	PAH (sum) */
1	1.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
8	1.8	0.5	0.8	0.5	0.7	0.3	4.6
11	1.8	0.4	0.7	0.4	0.7	0.3	4.3
18	1.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

*/Commonly in Poland assumed, content of PAH<100 µg/kg of dry mass of soil as non polluted soil ("very pure").

Table 6. Depth of ground water and bulk density of surface layer during spring (April) 1998

Measurement and sampling site	Mean bulk density Mg/m^3	Average depth of ground water (m)
Arable fields - cultivated (spring ploughing) and sown with spring cereals	1.40	0.9
Arable fields - non cultivated	1.60	0.6
Grasslands - non renovated	n.d.	0.3

applied, the yields did not vary significantly from long-term averages. Of course, a much more negative impact of flooding waters was observed for the existing (during inundation) plants and sward on grasslands. All the cultivated plants as well as sward on grasslands were destroyed completely. In the spring of 1998, on some arable fields, the residues of damaged plants were incorporated into the soil during spring ploughing. But the area of damaged grassland was not renovated in spring, and did not show any reasonable productivity in 1998. This relatively minor negative impact on the soil cover in the Odra Valley near Wrocław was shown by Szerszeń *et al.* [5]. The impact of flooding waters on the soil properties depends mainly on quality of the inundating water (e.g. amount and kind of sediments, concentration and kinds of chemical compounds dissolved in water, velocity of inundation and kind of soil and plants cover).

CONCLUSIONS

1. Long purposeful inundation with flood did not cause significant negative effects on basic chemical and physical soil properties on the Rybocice polder near Świecko.

2. No noticeable contamination with heavy metals (Pb, Cu, Zn, Cd, Cr and Mn) or policyclic aromatic hydrocarbons (PAH) was observed.

3. Mean crop yields one year after flooding when appropriate agrotechnical practices were applied, did not vary significantly from long-term averages.

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