IOŚ-PIB OCHRONA ŚRODOWISKA I ZASOBÓW NATURALNYCH
ENVIRONMENTAL PROTECTION AND NATURAL RESOURCES 2016

DE GRUYTER OPEN

VOL. 27 NO 2(68): 23-31
DOI 10.1515 /OSZN-2016-0012

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Chemical properties of selected soils of the Ina Valley near Sławęcin village

Właściwości chemiczne wybranych gleb doliny rzeki Iny koło Sławęcina

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Keywords: Ina valley soils, chemical properties, macroelements, mucky process
Słowa kluczowe: gleby doliny Iny, właściwości chemiczne, makroelementy, proces murszenia

Abstract
The research area is located in the Ina Valley of the West Pomeranian Voivods hip, along the border between two counties Choszczno and Stargard. The majority of this area is covered by the largest wetland in Western Pomerania, which is under legal protection. The aim of the study was to identify chemical properties and typological variability of organic soils of the Ina Valley. On the basis of field studies, four sites that were characterised by the main soil types occurring on the study area were designated. By the river bed, a narrow strip of alluvial, clay-organic sediments was found, from which muddy-gley soils developed. The largest part of the central valley was composed of organic low moor peat deposits, from which organic fibric-muck soils, in the third degree of decomposition, evolved. The edge of the valley, on shallow organic sediments, was covered by highly decomposed organic sapric-muck and mucky soils. The richest resources of organic matter were recorded in fibric-muck soils and the poorest in muddy-gley soils. The reaction of soils derived from peat was slightly acid or neutral and alkaline for alluvial deposits. All examined soils were characterised by a very low content of available phosphorus and potassium whereas the amount of available magnesium varied, depending on the soil subtype. Very low concentrations of available magnesium were obtained in sapric-muck and mucky soils, medium in muddy gley soils and high or very high in fibric-muck soils. Total forms of microelements were present in considerable quantities and a very high share of available potassium, magnesium, calcium and sodium in relation to total forms, in fibric-muck soil, attracts attention. In the case of other soil subtypes, only a high share of available calcium is observed.

Streszczenie
Badany obszar doliny rzeki Iny leży w województwie zachodniopomorskim, na styku powiatów: choszczeńskiego i stargardzkiego. Występują tu najrozleglejsze na Pomorzu Zachodnim, objęte ochroną prawną mokradła. Na podstawie przeprowadzonych badań terenowych wyznaczono cztery punkty charakteryzujące główne typy gleb jakie występują na analizowanym obszarze doliny Iny. Przy korycie rzeki stwierdzono wąski pas namułów o charakterze ilasto-organicznym, z których wytworzyły się gleby mułowo-glejowe. Największy obszar w centralnej części doliny zajmują osady organiczne torfu niskiego, występują tu gleby organiczne fibrowo-murszowe o trzecim stopniu zmurszenia. Natomiast na skraju doliny na płytkich osadach organicznych występują silnie zmurszałe gleby organiczne saprowo-murszowe oraz gleba murszowate. Najzasobniejsze w materię organiczną były gleby organiczne fibrowo-murszowe, natomiast najuboższe mułowo-glejowe. Odczyn gleb wytworzonych z torfu był lekko kwaśny bądź obojętny natomiast osadów aluwialnych zasadowy. Wszystkie badane gleby charakteryzowały się bardzo niską zawartością przyswajalnego fosforu i potasu natomiast przyswajalnego magnezu była zróżnicowana w zależności od podtypu gleb. Bardzo niskie ilości przyswajalnego magnezu stwierdzono w glebach saprowo-murszowych i murszowatych. Średnią ilość magnezu przyswajalnego w glebie mułowo-glejowej, a wysokie i bardzo wysokie w glebach fibrowo- murszowych. Formy ogólne mikropierwiastków występują w znacznych ilościach, przy czym zwraca uwagę bardzo wysoki udział form przyswajalnych w stosunku do ogólnej zawartości potasu, magnezu, wapnia i sodu w glebie fibrowo- murszowej. W przypadku pozostałych podtypów gleb stwierdzono tylko wysoki udział przyswajalnego wapnia.

1. INTRODUCTION

The areas within the boundaries of watercourses hold great natural and agricultural value. Their characteristic feature is their hydrological diversity. Depending on the speed of water flow, duration and frequency of flooding, the spatial distribution of sediments changes and lowering ground water table beyond soil profile considerably alters air-water relations initiating the mucking process [Jakubus et al. 2013]. These factors have a significant influence on the structure and transformation of the soil profile. As a result, even on a small area, there is a great typological diversity of soils [Kitczak et al. 2011, Niedźwiecki et al. 2010]. As observed in recent years, the intensified process of wetland degradation requires constantlydmonitoring. The slightest

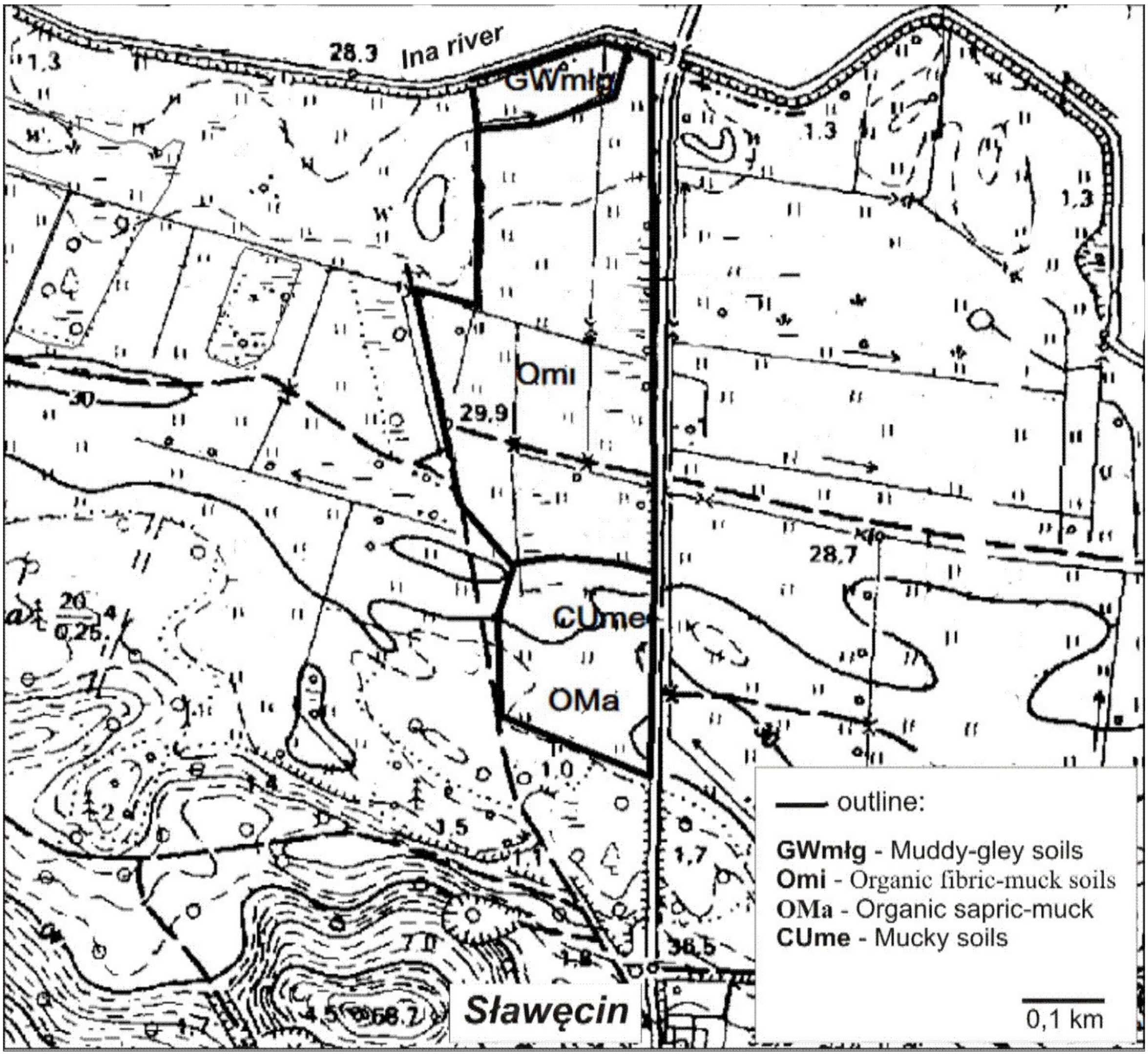

Figure 1. Area of investigations.

fluctuations in water and soil conditions result in sweeping transformations of vegetation cover. Many researchers point to the need for further detailed studies and proper management of invaluable wetlands [Gawlik et al. 1995, Kondratiuk et al. 1995, Malinowski 2012]. The wetlands of the Ina Valleyoare the largest in Western Pomerania. Little is known about their stratigraphy, soil properties and the degree of anthropogenic transformations. Therefore, the aim of the conducted studies was to determine the chemical properties and typological variations of the soils in the analysed area of the Ina Valley.

2. MATERIALS AND METHODS

Field studies were carried out in 2012, in the left side of the Ina river valley, near Sławęcin village (Fig. 1). On the basis of field observations and preliminary boreholes, four objects characteristic of main soil types were designated and one profile was made in each of them. From the determined and described genetic horizons, 21 samples were collected for laboratory analyses. Thengrain-size of mineral samples was established by the method of Boycouss Cassagrande, modified by Prószyńsk, soil colour was fixed on the basis of revised standard soil color charts [Oyama, Takehera 2003]; pH in H_2O and KCl was determined by electrometric method; organic matter by ignition at the temperature of 550°C in a muffle microwave oven (Milestone mls 1200 pyro); total carbon, nitrogen and sulphur by means of elementary analyser (CHNS-O, Costech, Italy). Using the obtained results,gthe C:N ratio was calculated. Atomic absorption spectrophotometer Unicam Solar 929 was used for determination of macroelements solved in 0.5 mol dm^{-3} HCl (PN-R-04024: 1997) and the total content of macroelements soluble in the mixture of concentrated acids HNO_3+$HClO_4$, (PN-ISO 11466: 2002) and phosphorus was determined colorimetrically. The results of laboratory studies were subjected to statistical analysis. The coefficients of correlation were calculated by means of the prograe Statistica 10.0 PL.

3. RESULTS AND DISCUSSION

The Ina river belongs to lowland rivers and i, predominantl, fed by groundwater originating from the Pleistocene aquiferous layer [Prawdzic 1962]. In its middle course, from Recz to Stargard, its gradient falls to ca 0.4%. The river flows here in a well-shaped valley whose width reaches a few kilometers [Winkler 2001]. This part of the valley was drained at the end of the 1 th century, whereas many objects were constructed in a post-war period in the 196's and 197's. The area covering ca 6000 ha of grassland was irrigated mainly by open ditches serving also as a drainage. On the section of the Ina river adjoining that area, there are three weirs (in Żukowo, Suchań and Wapnica), some locks and sills stabilising the bottom and the rate of water discharge from the river basin. In the 1980s, hydrotechnical works were stopped as well as the maintenance of the whole hydrological network. Moreover, in the 199's, intensification of agriculture was gradually being reduced. Much of abandoned grassland was afforested.yMany-year studies on water balance in the Ina river valley revealed a growing trend in water outflow despite lower precipitation and more intensive evaporation. The author attributes this trend to the effects of land drainage in the 197's [Winkler 2001].sStudies conducted in the Ina river valley, in the vicinity of Sławęcin village, showed that the area is covered with organic, mineral-organic and mineral sediments of varying thicknesses. Close to the river bed, clay-organic sediments were deposited, from which muddy-gley soils developed [PSSS 2011]. The central part of the valley is filled with a low peatland with organic fibric-muck soils whereas its edges are occupied by the mosaic of mucky soils and shallow, highly decomposed, organic, sapric-muck soils. The entire valley constitutes a monotonous topographically plain, with slightly marked microrelief.

Drainage of wetlands for agricultural us, results in the changes in the chemical and physical properties of soils and contributes to their degradation. The changes in chemical properties of soils and wetlands differ in intensity and depend, first of all, on moisture, genetic kind of organic matter, weather conditions as well as land use and management [Pawluczuk and Szymczuk 2008].

3.1. Muddy-gley soils (GWmłg)

Muddy-gley soils [PSSS 2011] are formed during a bog formation process, under conditions of strong hydration, at water table in the surface soil layer (50 cm). Saturation with water results in redox conditions and strong anaerobiosis of entire soil profile. Considerable fluctuations of groundwater level throughout the year favour a periodical aerobiosis [Malinowski 2012, Okruszko and Oświt 1969]. The muddy-gley soils developed from muddy-limnic sediments of amorphous nature were examined. In the past, the area was occupied by the old-river bed, slowly being filled with gyttja and silt but a considerable amount of mineral matter means that they were systematically modified by alluvial processes of the Ina river. At present, this area has been drained and used as an extensive pasture.

Cessation of limnic and alluvial processes, drainage and the use of silt-covered area for agricultural purpose contributed to the intensification of oxidation process in its upper part and development of muddy-gley soils.

The limnic origin of sediments shapes the morphology and chemical properties of muddy-gley soil. It has a well-developed humus horizon with a sub-horizon. L1 (0-15 cm) overgrown with plant roots, of crumble structure and L2 (15-35 cm) of coarser clod structure. Originating from drifted material, humus horizon and its sub-horizons contained 13.22 17.77% organic matter and 5.44 9.31% total carbon. Mineral-organic sediments lying below humus horizon, depending on genetic horizon, contained 12.50 21.83% organic matter and 8.55 14.35% total carbon (Table 1). The content of total nitrogen and sulphur were directly correlated with the content of organic matter (Table 3) and were high, typical of mineral-organic soils. Almost in the whole profile (except the topsoil 0-15 cm), small shells of molluscs and precipitated calcium carbonate, affecting soil reaction, were found. The reaction of L1 horizon was close to neutral (pH_{KCl} 6.87) but alkaline in lower horizons (pH_{KCl} from 7.41 to 7.56) (Table 1). The lower pH of 15-cm surface layer in relation to the layers lying underneath results from a more intensive process of mineralisation of the organic matter and leaching of basic cations downward in the soil profile by precipitation water. In view of limit values for surface layer [Kabata-Pendias et al. 1993], the total content of sulphur was very high in the depth of 100 cm.

Soils developed from mud are characterised by differentiated soil reaction [Kalembasa et al. 2001, Wicik 2001, Roj-Rojewski 2009], and bog, post-bog and gley processes favour their acidification [Laskowski 1985, Okruszko 1969]. According to Bieniek and Łachacz [2012], the ratio of total carbon to total nitrogen is considered as an indicator of soil biological activity. The narrower it is the more available nitrogen is to plants, whereas the wide C:N ratio causes nitrogen proteinisation. The muddy-soil under stud , despite high moisture, had a favourable C:N ratio, which indicates a good microbiological activity in its humus horizon (Table 1). Similar favourable C:N ratio was observed in the soils developed from mud in the river valleys o: Liwiec [Kalembasa et al. 2001], the Ina [Niedźwiecki and Trzaskoś 1999], the Dziwna [Niedźwiecki et al. 2006a], the Rega [Niedźwiecki et al. 2006b] or the mouth of the Warta [Malinowski 2008 and 2012]. In the entireeprofile (Table 2), this soil had a very low content of soluble in 0.5 $mol \cdot dm^{-3}$ HCl phosphorus and potassium and generally medium content of magnesium in comparison with fertiliser guidelines [IUNG 1990]. It was found that there was a very high share of total potassium in comparison with a small amount of its available forms (1.20-2.00% of the total content). It is the evidence for strong fixation of potassium by clay-organic sediments. The available calcium turned out to occur in the highest quantities. Similar small amounts of available phosphorus and potassium and medium and high amount of magnesium were found in the soils of the flood terrace in the mouth of the Wisła and Odra rivers examined by[Malinowski (2012] and the soils of Krasiborska Kępa Island analysed by[Niedźwiecki et al. (2002].

3.2. Organic fibric-muck soils (OMi)

The middle part of the valley is filled with a low peatland developed from fibric peat, strongly decomposed on the surface. Due to the past irrigation and drainage of that are , the surface of that deposit underwent an intensive mineralisation and transformation in a mucky process. As a result, organic fibric-muck soils [PSSS 2011] developedein this part, with the following sequence of genetic horizons: OM1-OM2-OM3-OTi1-OTi2.

In the surface layer of peatland, a well-developed muck horizo, was distinguishe . It comprised distinct sub-horizon : a soddy sub-horizon with a fine-grained structure, a sub-soddy sub-horizon of coarser-grained structure and a transitional clod sub- horizon.

Below the muck horizon, there was fibric peat with well-preserved plant remnants. The process of humification slightly impoverished the upper part of peatland in organic matter (from 79.10% in OM1 to 89.39% in OM3). The layers of fibric low moor peat were rich in organic matter (from 86.60 to 88.45%). The content of total carbon was closely correlated with organic matter (Table 3). Soil reaction to the depth of 100 cm was slightly acidic (pH_{KCl} from 6.03 to 6.26) and neutral at the depth of 100-200 cm (pH_{KCl} = 7.19).

The content of total nitrogen ranged from 2.89 in peat (OTi1 and OTi2) to 2.97% in muck (OM1, OM2 and OM3). The accumulation of total nitrogen in surface muck horizons resulted from mineralisation and decomposition of organic matter.

C:N ratio was fairly wide, within the range 12.24 16.72% the lowest, indicating the microbiological transformation of organic matter was recorded only in the top two first muck horizons (Table 1).

Total sulphur content was similar in the whole profile: from 0.40% (III degree) to 0.50% (IV degree), which according to boundary values was very high and reflected anthropogenic contamination [Kabata-Pendias et al. 1993].

In surface muck layers, a larger accumulation of available phosphorus, potassium and sodium was found than in transitional and peat layers. However, the content of available magnesium and calcium was varied (Table 2). In comparison with boundary values, the resources of phosphorus and potassium were very low and available magnesium high and very high in the whole profile [IUNG 1990].

In the soddy and sub-soddy sub-horizons, in comparison with peat, there was a markedly higher share of available phosphorus, potassium, calcium and sodium in their total content. In the case of magnesium, a reverse relationship was found, generall, (except the soddy sub-horizon) available forms amount to 90% of total content of this element (Table 2).

Table 1. Basic chemical properties of examined soils.

Horizon description and thickness [cm]	Loss on ignition [%]	pH		C	N	S	C:N
		H_2O	KCl	total			
				[%]			
Muddy-gley soils (GWmłg)							
L1 [0–15]	17.77	7.54	6.87	9.31	0.85	0.18	10.95
L2 [15–35]	13.22	7.84	7.48	5.44	0.50	0.11	10.88
Lc3 [35–55]	16.71	8.14	7.43	9.00	0.76	0.16	11.84
Lc4 [55–100]	21.83	7.68	7.41	14.35	0.90	0.20	15.96
Lc5 [100–200]	12.50	7.85	7.56	8.55	0.52	0.07	16.44
Organic fibric-muck soils (OMi)							
OM1 [0–10]	79.10	6.28	6.26	36.35	2.97	0.50	12.24
OM2 [10–16]	81.38	6.18	6.13	40.82	3.09	0.47	13.21
OM3 [16–28]	89.36	6.27	6.21	47.82	2.86	0.41	16.72
OTi1 [28–100]	86.60	6.59	6.03	46.89	2.84	0.40	16.51
OTi2 [100–200]	88.45	7.29	7.19	48.62	2.94	0.46	16.54
Organic sapric-muck (OMa)							
OM1 [0–12]	18.80	6.20	6.19	11.14	0.98	0.41	11.37
OM2 [12–26]	22.29	6.28	6.26	19.87	1.57	0.78	12.66
OM3 [26–50]	54.26	6.15	6.14	34.18	2.39	0.86	14.30
OTa [50–55]	44.47	6.78	6.16	30.73	1.75	0.82	17.56
A [55–80]	4.17	7.15	6.69	2.30	1.11	0.16	2.07
Cg [80–100]	1.44	6.82	6.34	0.79	0.05	0.02	15.80
Mucky soils (CUme)							
Au1 [0–14]	18.67	7.05	6.65	10.74	0.90	0.62	11.93
Au2 [14–24]	22.16	6.84	6.44	11.37	0.95	0.81	11.97
Au3 [24–34]	12.31	6.92	6.45	7.05	0.55	0.26	12.82
A [34–60]	7.56	7.18	6.75	3.25	0.23	0.03	14.13
Cg [60–100]	1.51	7.36	6.86	0.80	0.05	0.01	16.0

Table 2. Content of macroelements [mg·kg^{-1}].

Horizon and thickness [cm]	P	K	Mg	Ca	Na	P	K	Mg	Ca	Na
	HCl at concentration 0.5 mol· dm^{-3}					Concentrated $HClO_4$ and HNO_3				
Muddy-gley soils (GWmłg)										
L1 [0–15]	237.6	38.8	423.6	7555.0	128.5	1958.0	1946.0	2376.0	8265.0	395.0
L2 [15–35]	217.8	20.2	352.8	6985.0	59.5	2156.0	1694.0	1907.0	7350.0	373.0
Lc3 [35–55]	204.6	31.3	714.0	20660.0	11.5	2486.0	2283.0	2921.0	23080.0	353.8
Lc4 [55–100]	213.4	19.8	704.0	67400.0	99.2	2332.0	1344.0	2239.0	72140.0	353.8
Lc5 [100–200]	314.6	18.0	638.0	46440.0	53.7	1826.0	1252.0	1832.0	49990.0	199.3
Organic fibric-muck soils (OMi)										
OM1 [0–10]	275.0	197.5	1232.0	13060.0	257.3	1672.0	386.7	958.5	20630.0	381.7
OM2 [10–16]	176.0	132.3	1101.5	17000.0	245.7	1474.0	226.8	1174.0	20100.0	389.8
OM3 [16–28]	85.8	27.7	1022.5	18020.0	184.0	968.0	96.2	1070.0	18290.0	343.0
OTi1 [28–100]	74.8	12.2	1122.5	14140.0	173.7	792.0	78.3	1196.0	56160.0	354.4
OTi2 [100–200]	88.0	24.0	1514.0	13916.0	136.7	770.0	76.6	1552.0	26550.0	381.1
Organic sapric-muck soils (OMa)										
OM1 [0–12]	94.6	30.6	102.1	595.0	19.0	1056.0	446.6	510.0	6190.0	174.0
OM2 [12–26]	70.4	22.7	57.0	10970.0	13.4	1078.0	142.2	245.0	26425.0	156.1
OM3 [26–50]	63.8	21.6	49.9	12675.0	21.0	946.0	262.9	376.0	23680.0	161.8
OTa [50–55]	59.4	14.7	43.3	12990.0	21.5	1298.0	127.1	176.0	14030.0	168.3
A [55–80]	88.0	6.0	6.2	594.4	8.0	726.0	161.0	136.0	1331.0	137.2
Cg [80–100]	110.0	8.2	3.1	43.46	6.6	792.0	454.4	323.0	500.8	118.6
Mucky soils (CUme)										
Au1 [0–14]	81.4	24.3	199.6	5298.0	20.2	902.0	425.7	539.0	5710.0	188.1
Au2 [14–24]	57.2	16.8	70.1	5315.0	13.2	814.0	243.3	249.0	8870.0	149.9
Au3 [24–34]	52.8	10.5	21.6	5325.0	8.6	726.0	186.3	290.0	6419.0	160.9
A [34–60]	52.8	8.3	8.1	203.0	9.9	550.0	182.4	165.0	2391.0	141.1
Cg [60–100]	107.8	5.6	3.5	80.65	6.0	616.0	232.2	237.0	531.3	150.3

3.3. Organic sapric-muck soils (OMa)

Organic sapric-muck soils [PTG 2011] originate from highly decomposed sapric peat (contains a very small amount of fibr). Shallow organic sapric-muck soils occur on the edge of wetlands or on small sandy elevations of the valley. They are characterised by a narrow layer of highly disintegrated organic sediments.

The investigated soil had a well-developed muck layer M III to the depth of 50 cm, underlaid with a narrow layer of highly decomposed sapric peat, placed on loose sand.

The advanced process of decomposition caused a distinct impoverishment of surface soil layer in organic matter and total carbon.

The content of organic matter ranged from 18.80% in the soddy sub-horizon to 54.26% in transitional one, whereas it was 44.47% in the peat layer. Lying below, sandy humus layer and parent rock contained 4.17% and 1.44% of organic matter, respectively. Soil reaction was mostly slightly acid (pH_{KCl} ,.14-,.34), neutral (pH_{KCl} 6.69- only in the humus layer (Table 1).

The amount of total nitrogen wasdvaried from 0.05% for parent rock to 2.39% for transitional horizon C:N ratio in the surface layer (to 26 cm), and was quite favourable in the range 11.32 12.66% (Table 1). The content of total sulphur turned out to be positively correlated with the content of organic matter (Table 3). In comparison with limit values, the level of this element was very high in the whole profile [Kabata-Pendias et al. 1993].

The division and sub-division of the soil profile had a profound impact on the macroelement content (Table 2). The surface organic-mineral and organic horizons had richer resources of available potassium, magnesium, calciu, and sodium and poorer source of available phosphorus than deeper mineral horizons. The amounts of available phosphorus, potassium and magnesium for all genetic horizons were very low according to limit values for the agricultural purposes [IUNG 1990].

Table 3. Linear correlation coefficients between examined soil properties.

Variable	Loss on ignition	pH w H_2O	pH in KCl	C total	N total	C: N	S total	P_1	K_1	Mg_1	Ca_1	Na_1	P_2	K_2	Mg_2	Ca_2	Na_2
Loss on ignition	-	-–0.51*	–0.41	0.98*	0.96*	0.37	0.45*	-0.03	0.50*	0,80*	0.14	0.81*	–0.06	–0.36	0.12	0.36	0.59*
pH in H_2O	-	-	0.93*	–0.53*	–0.59*	–0.07	–0.62*	0.46*	–0.37	-0.02	0.33	–0.30	0.51*	0.74*	0.62*	0.13	0.18
pH in KCl	-	-	-	-0.43	-0.47*	-0.05	–0.57*	0.57*	–0.24	0.12	0.47*	–0.19	0.57*	0.72*	0.67*	0.24	0.26
C total	-	-	-	-	0.96*	0.42	0.54*	–0.11	0.40	0.74*	0.17	0.73*	–0.08	–0.39	0.08	0.40	0.52*
N total	-	-	-	-	-	0.19	0.56*	–0.06	0.54*	0.72*	0.11	0.77*	–0.06	–0.39	0.05	0.33	0.52*
C: N	-	-	-	-	-	-	0.09	–0.03	-0.08	0.30	0.36	0.19	–0.03	–0.14	0.09	0.42	0.12
S total	-	-	-	-	-	-	-	–0.41	0.18	0.00	-0.08	0.08	–0.20	–0.44*	-0.35	0.06	–0.10
P_1	-	-	-	-	-	-	-	-	0.48*	0.42	0.54*	0.41	0.81*	0.72*	0.73*	0.36	0.56*
K_1	-	-	-	-	-	-	-	-	-	0.53*	0.06	0.74*	0.29	-0.02	0.14	0.05	0.50*
Mg_1	-	-	-	-	-	-	-	-	-	-	.41	0.86*	0.31	0.08	0.57*	0.53*	0.84*
Ca_1	-	-	-	-	-	-	-	-	-	-	-	0.26	0.61*	0.38	0.58*	0.87*	0.38
Na_1	-	-	-	-	-	-	-	-	-	-	-	-	0.24	-0.05	0.36	0.37	0.80*
P_2	-	-	-	-	-	-	-	-	-	-	-	-	-	0.87*	0.85*	0.43	0.61*
K_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.85*	0.19	0.44*
Mg_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.50*	0.79*
Ca_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.42
Na_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Explanations: * - correlation significant at alfa = 0.05 for n = 21
1 – soluble in HCl at concentration 0.5 mol· dm $^{-3}$
2 – soluble in concentrated acids $HClO_4$ and HNO_3

3.4. Mucky soils (CUme)

Mucky soils [PTG 2011] develop as a result of very advanced mineralisation and humification of peat organic matter and the lack of mineral-organic bonds [Pawluczuk and Szymczuk 2008]. They are located, like organic sapric-muck soils, on the edges of the Ina Valley. Their characteristic feature is that they are the most transformed organic matter, the most decomposed and mineralised. Surface mucky horizons contained 12.31 22.16% organic matter whereas underlying humus had 7.56%. There were also numerous mottles of humus on the parent rock. Total carbon (from ,.05 1,.37%) and total nitrogen 0.55 0.95%) in mucky horizons shaped a favourable ratio of C:N (from 11.93 12.79%). Deeper in the soil profile, in mineral horizons, the amounts of total carbon and total nitrogen were reduced, whereas C:N ratio increased to 15.90. Soil reaction was slightly acidic or close to neutral, with greater acidification of mucky horizons in relation to underlying mineral horizons (Table 1).

Mineral-organic mucky topsoil contained more available potassium, magnesium, calcium and sodium distinctly than the sandy mineral layer of humus horizon and parent rock (Table 2). The determined amounts of available phosphorus, potassium and magnesium were very low [IUNG 1990). In the light of small quantities of available forms, the resources of their total content looked favourable.

The analysed fibric-muck, sapric-muck and mucky soils were characterised by a relatively favourable C:N ratio, which exhibits intensive microbiological transformations of organic matter in muck horizons leading to its permanent transformation. In the opinion of Okruszko and Piaścik [1990], organic matter is less susceptible to biological transformations only at wide ratio of C:N. However, Łachacz [2001] states that a very narrow C:N ratio, i.e., below 5 points to soil exhaustion and degradation.

Niedźwiecki et al. [2006c, 2008] obtained similar C:N values in the drained soils of Gryfiński Polder within Międzyodrze. Generally, the soils developed from low moor peat have a wider C:N (above 15). Slightly acid and neutral soil reaction also deserves attention. Low acidity is connected with the inflow of spring and groundwater from the upland, abundant in calcium cations and old river bed filled with gyttja, containing a large share of calcium carbonate. On the whole, a slightly more acidification was observed in surface layers, which is linked to the ongoing muck-forming process. In the lower section of the Ina, near Sowno village, the reaction of peatlands is acidic [Niedźwiecki et al. 2010]. Very acidic or acidic reaction was found in the wetlands of the Odra Valley [Niedźwiecki et al. 2006c, Niedźwiecki et al. 2008], while in the peatlands of the Valley Ujście Warty, it ranged from acidic to slightly acidic [Malinowski 2012].

The Study results showed that the soils evolved from low moor peat (fibric-muck, sapric-muck, and mucky) had, in general, the resources of available potassium, phosphorus and magnesium typical of the majority of peat-muck soils of Western Pomerania [Niedźwiecki 2000, Niedźwiecki et al. 2003, Niedźwiecki et al. 2009, Niedźwiecki et al. 2010].

The progress of the mucky process turned out to have a pronounced influence on the content of available macroelements. Fibric-mucky soils had the richest macroelement resources and mucky soils the lowest. In general, in the muck horizon of all the examined soils, an increase in the amount of macroelements, mainly available phosphorus and potassium, was observed, in relation to lower horizons.

The examined soils were characterised by the high total content of macroelements (K, P, Mg, Ca, Na) soluble in concentrated acids $HClO_4$+HNO_3 typical of the Ina Valley [Niedźwiecki 2010].

It was found that the loss of organic matter and total carbon in the soils, originating from mud and peat at varying degrees of decomposition, is accompanied by an increase in pH in H_2O, decrease in total nitrogen, sulphur and available Mg and Na.

Besides, a significant relationship between soil reaction (pH_{KCl}) and the content of total nitrogen, total sulphur, available phosphorus, calcium and total forms of phosphorus, potassium and magnesium was also observed (Table 3). However, C:N ratio, an important indicator of microbiological activity, did not have a significant influence on all the examined chemical parameters of soils (Table 3).

4. CONCLUSIONS

On the basis of the conducted studies in the Ina Valley, near Sławęcin, the following are the conclusions:

1. Drainage and agricultural use of the studied area of the Ina river valley caused the transformation of morphological and chemical properties of soils. Limnic soils turned into muddy-gley soils, deep fibric peat was transformed into fibric-muck, strongly decomposed, soils and shallow sapric peat into sapric muck and mucky soils.
2. Organic fibric-muck soils had the richest resources of organic matter and muddy-gley the poorest. The reaction of the soil developed from peat was slightly acid or neutral and that from fluvial sediments alkaline.
3. All examined soils were characterised by a very low content of available phosphorus and potassium but a varying content of available magnesium depending on the soil subtype. Extremely low amounts of available magnesium were obtained in sapric-muck and mucky soil, medium in muddy-gley and high to very high in fibric-muck soil. Total forms of macroelements were abundant.
4. In the soils developed from low moor peat the third degree of decomposition was found and permanent grain structure. With the advancement of decomposition process C:N ratio was narrowing, the content of organic matter was decreasing as well as the content of available macroelements (P, K, Mg, Ca and,Na).and total content of P, Mg and Na. The percentage share of available macroelements in their total content was also reduced. In the case of muddy-gley soils, these transformations were not clearly marked.

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