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Wpływ wód zanieczyszczonych ściekami kopalni węgla na właściwości gleby dna stawów karpiowych

The influence of waters polluted with colliery wastes on the properties of the bottom soil of carp ponds

Abstract — Investigations were caried out on changes in the properties of heavy bottom soils of ponds under the influence of water polluted with wastes from a mine of pit coal. It was found that in the upper layer of polluted soils, apart from a change in the grain size composition and a very large increase in acidity and in the amount of organic matter, there also occurs a marked concentration of some chemical constituents. The increase in the content of sulphur (chiefly in the form of sulphates and free H_2SO_4), aluminium, total phosphorus, and exchangeable sodium and magnesium is particularly strongly marked. The degree of their salinity is relatively low. Soils of ponds supplied with water in the first sequence are subject to the greatest pollution. A high percentage of organic matter of polluted soils consists of free compounds of fulvic and humic acids, bitumens, and phenols. The paper ends with a discussion on the detrimental effects of this phenomenon and on the means of preventing them.

The increase in the degree and in the range of pollution of surface waters caused by the dynamic development of industry compels also carp pond farms to use various polluted waters. However, the use of these waters in carp ponds does not always entail disadvantageous effects. In many cases, where appropriate conditions exist (possibility of diluting or preliminary purification, lack of toxic compounds) it may even produce favourable results. For it gives the possibility not only of an inexpensive fertilization of ponds, but above all of a biological purification of a certain amount of wastes, which is of importance to the water economy. However, the utilization of polluted water in a pond farm as a rule necessitates some changes in the way of running it and an accurate discernment of the specificity of the properties of its environment. The living conditions of fishes in ponds flooded with water of a varying amount and kind of pollution can widely differ.

Within the last few years many works have been devoted to the influence of water pollution on the life of fish cultivated in ponds. However, in contradistinction to the agricultural utilization of wastes, little is known about the effects of pollution on the properties of the soil of pond bottoms and on the ecological consequences resulting from it. The obtaining of these data with regard to various polluted waters and to the quality of pond soils is necessary for the determination for such a specific pond environment, of rational measures of cultivation and fertilization.

Chemical changes of the properties of soils as the effect of recurring watering or floods of qualitatively varying flowing waste waters (also saline) were dealt with by D o n e e n and H e n d e r s o n (1960). K e l l e y (1963), S t r z y s z c z (1965), and H u s z (1968). The occurrence of micro-components in soils of ponds flooded with various polluted waters was investigated by Pa s t e r n a k and G l i ń s k i (1969). Moreover, investigations were started at the Laboratory of Water Biology of the Polish Academy of Sciences, aimed at determining the action on pond soils of waters polluted with factory organic wastes (S. L e w k o w i c z).

The purpose of the present study was to investigate on the example of the carp farm Wielikąt (Katowice province) the influence on pond soil of water polluted with the partly purified wastes of industrial establishments of a bituminous coal mine and with saline waters from the depths of this mine before introducing in this industrial establishment a closed water circuit.

Methods of investigations

The investigated pond farm is supplied both by polluted water brought in from the stream Syrynka and by almost pure water from the small stream Lubomka. This pure water serves to flood several fry and spawning ponds. In the production of fish the farm applies the so-called Malik system (Sz c z e r b o w s k i 1953), according to which the ponds are stocked in July and fished only in the autumn of the following year.

Samples of soil for analyses were collected from ponds supplied with polluted water directly (ponds Malik and Żabniak) and indirectly through another pond (Lubomski II). as well as from ponds with pure water (Nowik Górny, Tarlisko). In the polluted pond Lubomski II the soil for investigation was collected before the period of its fairly long desiccation and culture (sample No 2 — medium) and after cultivation (profile No 3). Moreover, for comparison, account was also taken of the properties of the sediment of the basin on the Łączany-Skawina canal, leading water from the Vistula, polluted for the most part with colliery wastes.

The analysis of the soils was carried out by determining the grain composition with the Casagrande-Prószyński method, the total amount of

organic matter according to Alten, the content of free humic compounds and bitumens with the Tiurin method, the total nitrogen according to Kjeldahl, the exchangeable Ca and Mg compleximetrically, K and Na photometrically, the reaction electrometrically, and the freely soluble phosphorus with the Wondrauschowa method. The chemical analysis of HCl extracts was carried out according to the generally accepted principles of the analysis of silicates. The content of sulphur bound with metals and disengaging itself in the form of H_2S after treating the soil with acid, was determined in a separate test. The water was analysed according to the method developed by Hermanowicz et al. (1967) and by Standard Methods (1955).

Results

The chemical composition of the water of the two streams supplying the ponds, as well as the water of the canal, is presented in Table I. As can be seen from these data, the polluted water of the stream Syrynka brought in to most ponds at Wielikąt, was characterized by a very large amount of suspension proceeding from the coal affluents of washeries, a medium O_2 content, an increased oxygenation in relation to pure waters and BOD_5 (3.5—7.3 mg O_2/l), a considerable total hardness (non-carbonate for the most part), and a very high content of sodium, sulphates, chlorides, magnesium, and potassium (sodium-sulphate type). Moreover, this water contained for the most part a moderate quantity of iron and a small or medium quantity of phenol compounds. Its detailed characteristics were reported in the author's earlier work (Pasternak 1966).

The chemical composition of the pure water from the stream Lubomka shows no particular characteristic traits, apart from a slightly higher content of sodium (inconsiderable pollution from the village). The water of this stream is well saturated with oxygen, it contains a moderate quantity of calcium and magnesium, a fairly large one of iron, and an average quantity of potassium, sulphates, chlorides, and phosphates.

The water from the canal is very poorly saturated with oxygen and contains much less total suspension, sodium, and sulphates than the polluted water of the stream Syrynka, but more iron and phosphates. Moreover, it shows a higher oxygenation than the water of this stream and a total hardness and content of phenols approximate to it.

The soils of the bottom of ponds at Wielikąt were formed of alluvial materials from the river Oder. These materials within the ponds supplied by polluted water consist of heavy clay loam and in the pure ponds of silt--clay deposits (Table II).

On account of the intense sedimentation of the mineral and organic suspension present in this water, there develops in the course of time on

Tabela I. Skład chemiczny wody potoków zasilających stawy gospodarstwa Wielikąt oraz kanału Łączany - Skawina (w okresie letnim)

Table I. Chemical composition of the water of streams supplying ponds of the farm Wielikąt and of the Łączany - Skawina canal (in the summer)

Woda Water	pH	Tlen Oxygen mg O_2/l	Utlenialność Oxidability mg O_2/l	Twardość ogólna Hardness in German °n degrees	Ca^{2+}	Mg^{2+}	K^+	Na^+	HCO_3^-	SO_4^{2-}	Cl^-	Żelazo Iron mg Fe/l	Fosforany Phosphates mg PO_4/l	Fenole Phenole mg/l	Zawiesina ogółem - Total Suspension - Total mg/l
					me/l										
Potok Stream Szyzyska	7,4	4,5	14,7	24,5	4,82	5,89	0,40	10,40	3,05	9,94	6,34	0,20	0,04	0,06	90-250
Potok Stream Lubomka	7,3	8,7	8,5	9,6	2,24	0,93	0,31	0,43	2,20	1,12	0,54	0,60	0,02	0,00	0
Kanał Canal Łączański	7,2	0,8	20,8	19,3	4,10	2,80	0,33	4,80	2,90	4,00	5,10	1,50	0,30	0,05	75-125

Tabela II. Skład granulometryczny gleb dna stawów oraz osadu basenu na kanale łączącym w %

Table II. Grain composition of soils of pond bottoms and of the sediment of the Łączny canal basin in %

Nazwa zbiornika Name of reservoir	Nr prof. No	Głębokość w cm Depth in cm	Średnica cząstek gleby w mm Particle diameter in mm						Suma Total
			1,0-0,1	0,1-0,05	0,05-0,02	0,02-0,006	0,006-0,002	<0,002	<0,02
Staw Malik Pond (Świerkloch)	6	0 - 12	31	15	30	7	1	16	24
		12 - 24	9	2	11	23	18	37	78
		24 - 49	7	3	6	18	20	46	84
		49 - 85	8	2	4	12	23	51	86
	7	0 - 6	19	4	23	19	14	21	54
		6 - 30	12	4	10	18	20	36	74
Staw Żabniak Pond	9	0 - 5	19	10	20	19	12	20	51
		5 - 25	16	7	17	14	15	31	50
Staw Lubomski II Pond	10	0 - 19	7	4	22	18	15	34	57
		19 - 51	8	6	18	19	13	36	58
		51 - 85	9	5	14	14	10	47	71
	3	0 - 5	8	16	23	18	10	25	53
	2	0 - 15	8	11	38	17	11	15	43
Staw Borek Górny Pond	11	0 - 17	17	14	39	15	3	12	36
		17 - 50	12	15	40	16	4	13	53
Staw Turlisko Pond	12	0 - 9	14	20	36	15	4	11	30
Basen na kanale Canal basin	0-2	0 - 10	12	4	16	34	22	12	28

the surface of soils of ponds flooded with polluted water an accumulative layer with a content of coarser grains (especially silty ones 0.1—0.002 mm) much higher than in the deeper layers of the primary soil, and lower of colloidal (<0,002 mm) ones. As a result of the mechanical differentiation of sediments the rapidity of the formation of this layer (thickness) and its grain size chiefly depend on the way of flooding the ponds. In ponds receiving polluted water directly from the supply the thickness of accumulative layers of their soils and the content of coarser grains is considerable, whereas in ponds flooded indirectly it is much smaller. Accumulative layers of soils of ponds flooded directly usually have a grain composition of silt deposits. The differentiation in the grain composition between the particular layers in the profile of the soil is less marked in polluted ponds which were more frequently cultivated (pond Lubomski II, profile 10).

The surface layer of soils of ponds supplied with polluted water contains a varying quantity of organic matter (Table III). In soils of ponds receiving this kind of water directly the content of organic matter in this layer is very high, ranging from 6.5 to 22.0 per cent, whereas in ponds flooded indirectly it amounts to only 3.0—6.0 per cent (according to a larger number of analyses than that presented in Table III). Hence it appears that in the last mentioned ponds the content of organic matter in the accumulative layer of the polluted soil does not greatly depart from the average one encountered in analogous layers of pure soils. A certain differentiation in the content of organic matter also occurs within one pond. It is usually higher in soils of the deeper parts of the pond or in those lying nearest to the point of water inflow. This is probably chiefly related with the flow of suspension density currents into the depressions of the bottom. In the profile of soils of ponds flooded with polluted water, especially of those placed under cultivation, there occurs a considerable shift of organic matter to the deeper layers. This fact has an effect on the extension of the range and intensity of reduction proceses (of the gleying-podsolisation process) in the soil of the bottom.

The organic matter of the surface levels of soils of polluted ponds differs in character from the average soil humus. It contains a certain amount of coal dust and crushed mass of detritus, which, as appears from investigations carried out on coal dumps (S k a w i n a 1965), mineralize with great difficultty. However, the not very wide C:N ratio (Table III) indicates that the share of this dust in the general organic mass of the soil is much smaller that is generally accepted. This is probably due to the fact that in polluted, highly eutrophied ponds the sedimentation of dust suspension is accompanied by an intensified development of various hydrophytes and consequently a greater inflow of autochthonous organic matter less resistant to decomposition. In shallow ponds of the investigated farm, flooded with polluted water through other ponds, a submerged vegetation develops particularly intensely, with the dominant forms *Myrio-*

Tabela III. Zawartość substancji organicznej, organicznego węgla, całkowitego azotu oraz wolnych związków humusowych w glebach stawów i w osadzie basenu kanału łączącego

Table III. Content of organic matter, organic carbon, total nitrogen, and free humic compounds in pond soils and in the sediment of the łączany canal basin

Nazwa zbiornika Name of reservoir	Nr prof. No prof.	Głębokość w cm Depth in cm	Substancja organiczna Organic matter %	Ogólna zawartość Total content %		C : N	Bituminy Bitumens		Wolne substancje humusowe (bez dekalcytacji) Free humic substances (without decalcification)			
									C - kwasów huminowych humic acids		C - kwasów fulwowych fulvic acids	
				C	N		g/100g gleby soils	% C ogółem total	% gleby soil	% C ogółem total	% gleby soil	% C ogółem total
Staw Melik Pond (Śmierkłocz)	6	0 – 12	22,50	13,05	0,82	15,9	0,757	5,80	0,313	2,40	0,375	2,87
		12 – 24	3,97	2,30	0,25	9,2	-	-	-	-	-	-
		24 – 49	2,91	1,69	0,16	10,6	-	-	-	-	-	-
		49 – 85	1,43	0,83	0,12	6,9	-	-	-	-	-	-
	7	0 – 6	13,20	7,65	0,48	15,5	-	-	-	-	-	-
Staw Zabniak Pond	9	0 – 5	12,80	7,42	0,45	16,4	-	-	-	-	-	-
		5 – 25	2,80	1,62	0,16	10,5	-	-	-	-	-	-
Staw Lubosel II Pond	10	0 – 19	5,69	3,30	0,28	11,8	0,178	5,25	0,116	3,42	0,148	4,36
		19 – 51	2,42	1,40	0,14	10,0	-	-	-	-	-	-
		51 – 85	1,49	0,86	0,11	7,8	-	-	-	-	-	-
	3	0 – 5	3,20	1,85	0,16	11,6	-	-	-	-	-	-
	2	0 – 15	5,94	3,45	0,32	10,8	-	-	-	-	-	-
Staw Nowik Górny Pond	11	0 – 17	2,90	1,68	0,17	9,9	0,092	3,17	0,084	2,89	0,120	4,13
		17 – 50	0,30	0,17	0,04	4,2	-	-	-	-	-	-
Staw Tarlisko Pond	12	0 – 9	4,80	2,78	0,25	11,1	-	-	-	-	-	-
Basen na kanale Canal basin	C_2	0 – 10	19,30	11,19	0,35	32,0	0,548	4,90	0,123	1,10	0,127	1,13

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phyllium spicatum L. and *Potamogeton trichoides* C h a m. et S c h l e c h t. Apart from the production of organic mass, this vegetation, in N a k e l' s (1968) opinion, contributes to the deterioration of oxygen conditions in the pond during the night. According to H a r t m a n and B r o w n (1966), *Myriophyllium spicatum* and *Elodea canadensis* show in this period a capability of accumulating in their tissues large quantities of methane. The exuberant development of plants is also the cause of the considerable variation of the reaction of the water of these ponds. The sediments of the basin on the canal, whose water is polluted not only by colliery wastes but also by those of the cellulose industry, show a much wider C:N ratio (Table III).

Another characteristic trait of polluted soils is that their accumulative layers contain an exceptionally large amount of free humic substances undergoing dissolution in water and mineralization much more readily than those bound with mineral components of the soil (Table III). The amount of these free humic compounds in soils of ponds directly supplied with polluted water is several times larger than in the soil of a pond with pure water (Nowik Górny). In the upper layer of the soil of the pond Lubomski II flooded with polluted water through another large pond, the content of these compounds is only slightly higher than in a pure soil. Polluted soils also show a much larger content of the so-called bitumens (resins, fats, tar). In all investigated soils free compounds of fulvic acids prevail over the humic ones.

Apart from an increase in the general content of organic matter and free humic compounds and a transformation of the grain size, also distinct chemical changes are noted in soils of ponds flooded with polluted water (Tables IV and V). As can be seen from the comparison of the chemical composition of polluted soils with pure heavy loam and clay soils (P a- s t e r n a k 1966a), these changes are relatively small and, in principle, concern the content of only some elements. They are most marked in the surface layers of soils of ponds receiving water directly from the supply. Taken as a whole, the accumulative layers of soils lying under polluted waters, compared with analogous layers of pure soils, show above all a much higher content of sulphur, aluminium, and phosphorus compounds soluble in 20 per cent HCl, and an only slightly higher content of sodium, potassium, and iron (fig. 1, Table IV). It is worth noting that the large percentage of aluminium and sulphur is present in these layers in freely soluble compounds (Table V) and presumably partly in the form of free sulphuric acid. The presence of a certain insignificant quantity of this acid in the soil of polluted ponds flooded directly seems to be evidenced by its very acid reaction, rarely noted in mineral pond soils of such considerable buffer capacity (Table V). Also B a r n e s' and R o m b e r g e r's (1968) investigations point to this demonstrating that surface waters polluted with wastes of a bituminous coal mine contain a large quantity of free

Tabela IV. Analiza chemiczna wyciągu 20 % HCl. Zawartość składników w % suchej masy gleby

Table IV. Chemical analysis of the extract of 20 % HCl. Content of components in % of dry soil mass

Nazwa zbiornika / Name of reservoir	Staw Pond Malik (Świerklocz)				Staw Pond		Staw Lubomski II	Staw Pond Nowik Górny		Basen na kanale Canal basin
Nr prof. / No prof.	6				10		2	11		C₂
Głębokość profilu w cm / Depth of profile in cm	0-12	12-28	24-49	49-85	0-19	51-81	0-10	0-17	17-50	0-10
SiO_2	0,76	0,60	0,65	0,62	0,63	0,68	0,67	0,54	0,56	0,56
P_2O_5	0,35	0,22	0,18	0,19	0,12	0,10	0,08	0,10	0,08	0,60
Al_2O_3	5,40	8,47	9,32	10,90	7,50	10,70	6,28	2,78	3,08	7,91
Fe_2O_3	4,60	6,10	5,65	8,10	3,15	5,20	3,10	1,65	2,40	0,57
$Fe\ O$	-	-	-	-	-	-	-	-	-	5,02
$Mn\ O$	0,03	0,03	0,04	0,04	0,02	0,03	0,03	0,02	0,04	0,08
$Ca\ O$	1,08	0,75	0,77	0,85	1,03	0,80	2,90	0,52	0,48	2,04
$Mg\ O$	0,93	1,15	1,15	1,33	0,98	1,05	0,76	0,50	0,40	1,48
K_2O	0,96	0,99	0,89	1,09	1,04	1,22	0,72	0,56	0,62	0,95
Na_2O	0,90	0,72	0,54	0,64	0,54	0,50	0,80	0,47	0,46	0,38
SO_3	1,52	0,48	0,39	0,35	0,43	0,26	0,76	0,31	0,24	0,85
$S/R_2S/$	śl.	0	-	-	0	-	śl.	-	-	0,19
Suma części rozpuszczalnych w HCl / Total of parts soluble in HCl	16,53	19,51	19,58	24,11	15,44	20,54	15,70	7,45	8,36	20,63
H_2O (105°C)	3,47	3,88	4,43	4,91	3,12	4,65	1,70	1,10	1,10	3,68
Strata żarowa / Loss on ignition	24,29	9,20	7,96	7,87	9,30	6,90	9,12	4,56	2,04	20,99
Suma części nierozpuszczalnych w HCl / Total of parts insoluble in HCl	55,85	67,50	68,15	63,31	72,25	68,08	73,58	87,10	88,59	54,75
Suma Total	100,14	100,09	100,12	100,20	100,11	100,17	100,10	100,21	100,09	100,05

Tabela V. Niektóre właściwości chemiczne gleb dna stawów oraz osadu basenu na kanale Łączańskim

Table V. Some chemical properties of pond bottom soils and of the sediments of the Łączany canal basin

Nazwa zbiornika Name of reservoir	Nr prof. No prof.	Głębokość w cm Depth in cm	Zasadowe kationy wymienne Basic exchangeable cations m.e./100 g gleby soils					Kwasowość hydrolit. Hydrolytic acidity	$pH/H_2O/$	Łatwo rozpuszczalne składniki Available components (0,1 n HCl) mg/100 g gleby soils			
			Ca	Mg	K	Na	Suma Total			Al_2O_3	Fe_2O_3	P_2O_5	SO_3
Staw Malik Pond (Świerkloch)	6	0 – 12	24,7	5,1	0,50	2,14	32,44	11,6	2,75	220,0	210,0	2,5	162,0
		12 – 24	13,9	5,2	0,30	1,83	21,23	-	4,20	-	-	6,0	-
		24 – 49	12,0	4,7	0,37	1,70	18,77	-	4,20	-	-	9,0	-
		49 – 85	10,5	1,1	0,30	1,55	13,45	-	4,35	-	-	9,0	-
	7	0 – 6	14,7	4,5	0,47	1,90	21,57	12,4	4,40	-	-	5,0	-
Staw Żabniak Pond	9	0 – 5	7,1	1,4	0,39	2,05	10,94	19,3	3,00	322,5	282,5	2,5	155,0
		5 – 25	-	-	-	-	-	-	4,35	-	-	1,5	-
Staw Lubomski II Pond	10	0 – 19	15,0	5,7	0,41	1,72	22,83	7,3	4,65	-	-	5,0	-
		19 – 51	10,0	5,7	0,29	1,17	17,16	-	5,25	-	•	2,0	-
		51 – 85	-9,7	1,0	0,28	1,18	12,16	-	5,35	-	-	2,5	-
	2	0 – 15	18,7	5,5	0,38	3,48	28,06	-	6,60	161,0	149,0	2,5	120,0
Staw Nowik Górny Pond	11	0 – 17	6,1	1,4	0,15	0,20	7,85	5,7	5,40	-	-	7,5	-
		17 – 50	5,7	0,8	0,13	0,29	6,92	-	6,30	-	-	2,5	-
Staw Tarlisko Pond	12	0 – 9	6,2	1,1	0,14	0,26	7,70	5,4	5,30	138,0	127,5	7,5	20,0
Basen kanału Canal basin	C_2	0 – 10	17,5	2,6	0,34	1,68	22,12	6,8	6,85	-	-	2,0	-

sulphuric acid. C a l d w e l l (1966) observed that the increase in the amount of elementary sulphur in the soil, oxidized to sulphuric acid, is accompanied by an increase in the acidity of the soil. Soils of ponds flooded with polluted water in a further sequence show a slightly smaller acidity. The desiccated strongly acidified bottoms of polluted ponds are overgrown in masses by *Juncus bufonius* L.

In contradistinction to the sediments of the basin on the Łączany—Skawina canal, only traces of sulphur were found in the surface layers of polluted soils in compounds of sulphides decomposed after pouring acid
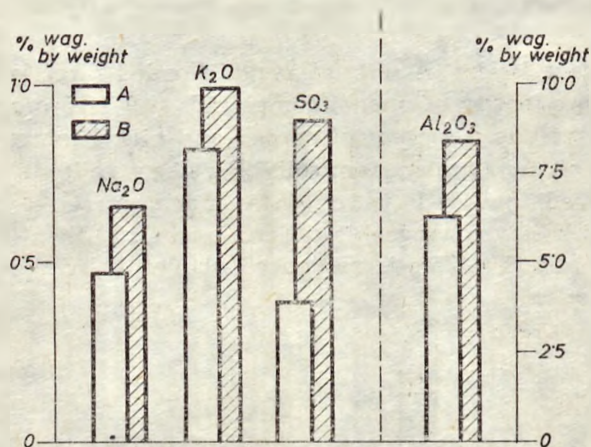
Ryc. 1. Średnia zawartość sodu, potasu, siarczanów i glinu (rozpuszcza'nych w 20% HCl) w ciężkich glebach stawowych zalewanych: A — czystą wodą; B — wodą zanieczyszczoną ściekami z kopalni.

Fig. 1. Mean content of sodium, potassium, sulphates, and aluminium (soluble in 20% HCl) in heavy pond soils flooded with: A — pure water; B — water polluted with colliery wastes.

with disengagement of H_2S over the soil. This probably is due to the fact that, in contradistinction to sediments, polluted pond soils mostly lie under water which is moderately or well saturated with oxygen and, moreover, are recurrently desiccated. However, one cannot exclude the possibility of a periodical occurrence of sulphur in reduced form (sulphides and other compounds) in humic layers of these soils. In some ponds there may occur in the zone near the bottom a certain deficiency of oxygen (during the winter season, or at night in strongly overgrown ponds). N r i a g u ' s (1968) investigations showed that in the slime of a lake poorly saturated with oxygen there occurred, apart from sulphides, hydrogen sulphate, primary sulphur, and sulphates, besides a large amount of a black amorphous substance of undetermined composition, soluble in acid. As can be seen from the chemical composition, of the water and soil (Tables I and IV), sulphates are the dominant form of sulphur in the investigated ponds.

The content of calcium in the surface layer of soils of ponds flooded directly with polluted water is much lower than is usually noted in soils lying under hard pure waters. This is presumably related with the predominance in the polluted water of calcium sulphates over carbonates more readily undergoing precipitation (in consequence of a biological consumption of free CO_2 in water). An amount of calcium approximate to that present in soils under pure waters was noted only in soils of the shallow pond receiving polluted water in a further sequence and in which vascular submerged vegetation developed in masses (high pH of water by day, oversaturation with oxygen, and more intense precipitation of $CaCO_3$).

In the surface layers of soils of ponds flooded directly with polluted water a certain quantity of phenol compounds (0.9—2.5 mg/kg of wet soil) was noted, as well as a content of copper and nickel increased in relation to such layers of pure heavy loam soils (P a s t e r n a k, G l i ń s k i 1970).

The analysed polluted water acts much more strongly on the composition of basic exchangeable cations in the soil than on the chemical composition (Table V). This is evidenced above all by the fact that soils
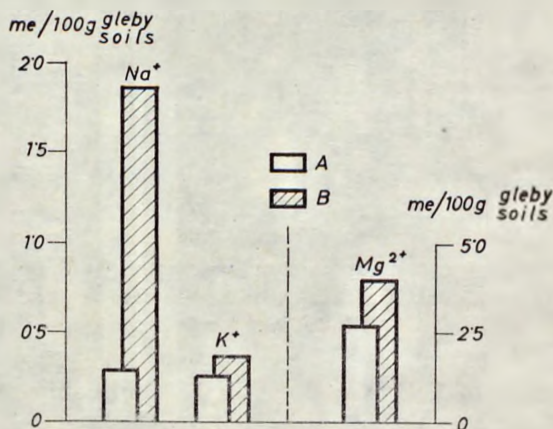
Ryc. 2. Średnia zawartość wymiennego sodu, potasu i magnezu w ciężkich glebach stawowych zalewanych: A — czystą wodą; B — wodą zanieczyszczoną ściekami z kopalni.

Fig. 2. Mean content of exchangeable sodium, potassium, and magnesium in heavy pond soils flooded with: A — pure water; B — water polluted with colliery wastes.

under polluted waters show a much higher content of exchangeable sodium and magnesium than the corresponding pure soils (fig. 2). The mean amount of exchangeable sodium in a sorptive complex of polluted soils (salinity) is more than five times larger than in qualitatively similar pure soils (taking into account all layers of the soil). According to K e l l e y (1963), sodium present in polluted water chiefly replaces calcium in the sorptive

complex of the soil. Experiments carried out by D o n e e n and
H e n d e r s o n (1960) showed that salts of low solubility (calcium and
magnesium carbonates and sulphates) occurring in water do not participate
in saturating the flooded soil with salt. Moreover, it should be noted that
in the investigated polluted soils a large amount of exchangeable sodium
also occurs in the deeper layers of the profile. This proves that in spite of
the considerable compactness of the soil, the freely soluble sodium salts
can be shifted deeper into its profile. Presumably, sodium penetrates far
into the investigated soils, chiefly with rain water during the period of
desiccation of the ponds. A large amount of exchangeable sodium in the
sorptive complex of soils reccurently flooded with water from a stream
polluted with colliery wastes was also noted by S t r z y s z c z (1965). An
increase in the content of exchangeable sodium in soils (salinity) is also
observed in the case of using saline polluted waters of another type for
their flooding. On the other hand, only minimal differences occur between
the investigated soils and the qualitatively similar pure ones in the amount
of exchangeable potassium (fig. 2). This is probably related with the small
concentration of this component in pond water. The humic layers of soils
of ponds flooded with polluted water directly from the supply are also
characterized by an exceptionally high hydrolytic acidity (Table V). Freely
soluble phosphorus in these strongly acid polluted soils occurs in small or
moderate quantities (Table V).

Discussion

Taken as a whole, changes in the properties of the soil of the bottom
of ponds under the influence of water (stagnant) polluted with wastes of
a bituminous coal mine are relatively very small, this particularly refering
to the general chemical composition of these soils. This is probably due in
great measure to a fairly long desiccation carried out in pond farms
(especially in the case of the system of cultivation applied in the
investigated farm), in the course of which part of the organic matter
accumulated in excess can undergo decomposition and the mineral matter
be partly washed out by rain water. Another explanation of this fact
would be that the polluted water is usually introduced into the ponds only
once in a larger mass. It also seems that the relatively good saturation
of the polluted water with oxygen, permitting a more rapid course of
biochemical processes of hydrolysis and neutralization of polluting
substances in the flooded soil, has a certain effect on the degree of
pollution of these soils. A lower O_2 content in the water of the investigated
pond farm may occur only in ponds strongly overgrown with submerged
vascular vegetation, in the night-time and in the winter fish-ponds, on
account (among other factors) of the interruption of processes of self-
-purification of water during the winter season both in the terrain of the
purification plant and in the section of the supply.

The differentiation of properties of soils occurring between the polluted ponds chiefly depends on their way of flooding. The properties of soils of ponds receiving polluted waters directly from the supply depart most from the average. On the other hand, soils of ponds flooded through another pond show a much smaller degree of pollution.

Pollution acts most intensely on the surface layers of the soil. This is marked above all by a large increase in these layers in the amount of coarser mineral grains (0.1—0.02 mm) and of organic matter, related with the sedimentation of the suspension of coal dust present in the water. A high percentage of organic matter accumulated in the polluted soils consists of well humified substances, including also the most freely soluble in water free compounds of fulvic and humic acids. The amount of each of the last mentioned compounds in a strongly polluted soil is several times larger than in a pure soil collected in the investigated farm (pond Nowik Górny). This also refers to the content of bitumens. Hence the conclusion can be drawn that organic matter accumulated in excess in polluted soils may, besides phenols, have a disadvantageous effect on the formation of the level of the O_2 content in pond water, especially under unfavourable climatic conditions (winter).

In consequence of the precipitation from polluted water of solid and dissolved substances taking place in the upper layers of soils, there occurs, apart from a considerable increase in organic matter, also a concentration of some chemical elements. These layers show, above all, an increase in sulphur soluble in 20 per cent HCl, chiefly in the form of sulphates, aluminium, phosphorus, and exchangeable sodium and magnesium.

Of the mentioned chemical properties of the soil the most important to the development of living conditions of organisms in polluted ponds is the accumulation of sulphates in the soil. Their content in the polluted water of the investigated ponds does not usually exceed 500 mg SO_4/l (P a s t e r n a k 1966). In the light of the data reported by P r o w s e (1965) and S t a n g e n b e r g (1966), neither has this content of sulphates any marked disadvantageous effect on fresh-water fish, the more so as the examined water contains no large amount of heavy metals, which could form with sulphates some more toxic compounds (P a s t e r n a k, A n t o-n i e w i c z 1970). On the other hand, it seems that the simultaneous considerable store of these compounds in the soil (exceeding the ecological optimum) is a disadvantageous phenomenon in carp ponds. Sulphates in an anaerobic environment of the soil may, with the co-operation of microorganisms, undergo reduction to hydrogen sulphide which, in spite of its rapid oxidation or volatilization (S o r o k i n 1968), always has a certain disadvantageous effect on aquatic organisms. As was reported by N i e w o l a k (1969), the environment particularly favourable to the development of bacteria-reducing sulphates are soils rich in calcium sulphate and organic matter, from which they draw the hydrogen required

in the reduction process. Thus, any reduction of the level of oxygen in the zone of water near the bottom in this kind of polluted ponds (which, as was earlier noted, can occur in some of them) may bring fairly grave consequences. Moreover the not killed sulphuric acid (formed partly also as a result of the absorption of the cation by plants) contributes to the moving of calcium from the soil, and to the latter's very strong acidity. This in consequence leads to the decomposition of clay minerals of the montmorillonite group and to the liberation of a large amount of aluminium and iron. It may be that the strong acidity of polluted soils is in some measure also the reason for their low content of easily assimilable phosphoric compounds.

Presumably, the saturation of the sorptive complex of polluted soils with sodium (salinity) is not strong enough to bring about in the pond environment any essential disadvantageous consequences. The deterioration of the microstructure due to salinity and the reduced permeability usually observed in cultivated soils fertilized with saline wastes, may take place in pond soils (within a limited range) only during the period of their desiccation. This moderate content of exchangeable sodium in polluted pond soils is probably determined not so much by the concentration of this element in the water, as by the large share of calcium in the composition of the water and the leaching action of rain water during the period of desiccation of the ponds. According to Kelley (1963), the exchange in the soil of calcium cations for sodium greatly decreases when the calcium content in the water reaches 35 per cent of the total amount of its cations. Moreover, on account of the leaching action of pond water, no large concentration of soil solutions can occur in a flooded soil.

In the light of the data presented above it appears that ponds flooded with water of this kind and degree of pollution require some additional measures of cultivation. Broadly speaking, this means that such ponds should be desiccated as long as possible and should be subjected to agrotechnical operations to activate the mineralization of the large amount of organic matter and phenols accumulated in their soils and induce a better washing out by rain water of disadvantageous mineral compounds present in the soil. Mechanical cultivation (ploughing) can also be a great help in fighting against the submerged vascular vegetation excessively developed in some ponds. Ponds receiving polluted water directly from the supply require frequent and most intensive liming of the desiccated bottom, in order to suppress the considerable acidity of the soil (see hydrolytic acidity Table V) and the stabilization in it of iron and aluminium. Fertilizing with lime will also contribute in moving from the soil a certain amount of phosphoric compounds. The disadvantageous effect of flooding ponds with this kind of polluted water can also be partly eliminated by an appropriate selection of nitrogen fertilizers.

STRESZCZENIE

W publikacji przedstawiono wyniki badań nad wpływem wody zanieczyszczonej ściekami kopalni węgla kamiennego na właściwości ciężkich gleb dna stawów karpiowych w gospodarstwie Wielikąt (woj. katowickie). Gospodarstwo to, oprócz zanieczyszczonej wody doprowadzanej z potoku Syrynka, korzysta również z prawie czystej wody potoku Lubomka. Skład chemiczny wody obu tych potoków przedstawiono w tabeli I.

Próby gleby do analiz zostały pobrane ze stawów zasilanych zanieczyszczoną wodą bezpośrednio (Malik i Żabniok), pośrednio (Lubomski II) oraz ze stawów o czystej wodzie (Nowik Górny, Tarlisko). Dla porównania wzięto także pod uwagę właściwości osadu basenu na kanale wodnym Łączany—Skawina, prowadzącego wodę w dużym stopniu zanieczyszczoną ściekami kopalni.

Ogólnie biorąc, zmiany właściwości gleb, powstałe pod wpływem (stojącej) wody o tego rodzaju i tym stopniu zanieczyszczenia, są stosunkowo niewielkie. Szczególnie w małym stopniu zmienia się ogólny skład chemiczny gleb. Wiąże się to z całym szeregiem cech środowiska stawowego (osuszanie, jednorazowy większy dopływ wody, niezłe natlenienie wody). Z gorszym natlenieniem wody w badanym obiekcie należy się liczyć jedynie w stawach mocno zarośniętych zanurzoną roślinnością naczyniową w godzinach nocnych oraz w zimochowach, z uwagi na zahamowanie w okresie zimowym procesów samooczyszczania się wody.

Występujące zróżnicowanie właściwości gleb pomiędzy zanieczyszczonymi stawami zależy głównie od sposobu ich nawadniania. Najbardziej odbiegają od przeciętnej właściwości gleby stawów, zaopatrywanych zanieczyszczoną wodą wprost z donośnika.

Zanieczyszczenia najintensywniej oddziałują na powierzchniowe warstwy gleby. Wyraża się to przede wszystkim dużym wzrostem w tych warstwach zakwaszenia (tabela V), ilości grubszych ziarn mineralnych (tabela II) oraz materii organicznej (tabela III), związanym z wytrącaniem się z wody zawiesiny pyłu węglowego i rozpuszczonych substancji. Znaczny odsetek zaakumulowanej w zanieczyszczonych glebach materii organicznej stanowią dobrze zhumifikowane substancje, w tym także najłatwiej rozpuszczalne w wodzie wolne związki kwasów fulwowych i huminowych. Ilość każdego z tych ostatnich związków jest w silniej zanieczyszczonej glebie kilkakrotnie większa niż w czystej, pobranej w omawianym gospodarstwie. Dotyczy to również zawartości bitumin i fenoli. Z tego można wnosić, że zaakumulowana w nadmiarze w zanieczyszczonych glebach materia organiczna może obok fenoli odgrywać, zwłaszcza w niekorzystnych warunkach klimatycznych (zima), ujemną rolę w kształtowaniu się poziomu natlenienia wody w stawach.

Ponadto w górnej warstwie zanieczyszczonych gleb zachodzi także wyraźne polkoncentrowanie się niektórych składników chemicznych. W największym stopniu wzrasta w tych warstwach zawartość rozpuszczalnej w 20% HCl siarki (głównie w postaci siarczanów i wolnego $H SO_4$), glinu, fosforu oraz wymiennego sodu i magnezu (tabela IV i V, ryc. 1 i 2).

Z wymienionych chemicznych właściwości gleby, dla kształtowania się warunków bytu organizmów w zanieczyszczonych stawach, największe znaczenie ma fakt nagromadzenia się w niej siarczanów i wolnego $H SO_4$ (przy dużej obecności tych związków w wodzie — dochodzącej do 500 mg SO_3/l). Siarczany w anaerobowym środowisku gleby mogą bowiem, z udziałem mikroorganizmów, ulegać redukcji do siarkowodoru, który, jakkolwiek szybko się utlenia lub ulatnia, zawsze w jakimś stopniu wpływa niekorzystnie na organizmy wodne. Towarzyszący siarczanom w małej ilości niezobojętniony kwas siarkowy (powstały także w części w wyniku pobrania przez rośliny kationu) przyczynia się, poza silnym zakwaszeniem gleby i uruchomieniem z niej wapnia, do rozkładu minerałów ilastych grupy montmorylonitu i uwolnienia

dużej ilości glinu i żelaza. Silne zakwaszenie zanieczyszczonych gleb jest również w pewnym stopniu przyczyną stosunkowo małej zawartości w nich łatwo przyswajalnych związków fosforu (tabela V). Nasycenie kompleksu sorbcyjnego zanieczyszczonych gleb sodem (zasolenie) nie jest na tyle duże, aby mogło, jak się wydaje, wywoływać w środowisku stawowym jakieś istotne ujemne skutki. O tej umiarkowanej zawartości wymiennego sodu w zanieczyszczonych glebach stawowych decyduje prawdopodobnie nie tyle koncentracja tego pierwiastka w wodzie, co duży udział w składzie wody wapnia oraz ługujące działanie wód opadowych w okresie osuszania stawów.

W świetle powyższych danych widać, że stawy zalewane wodą o tego rodzaju i tym stopniu zanieczyszczenia, wymagają pewnych dodatkowych zabiegów pielęgnacyjnych i nawożeniowych. Najogólniej można powiedzieć, że stawy takie winny być jak najdłużej osuszane, a także co pewien czas poddawane zabiegom agrotechnicznym dla przyspieszenia mineralizacji zaakumulowanych w ich glebach dużych ilości materii organicznej i fenoli oraz lepszego wymycia z ich gleby przez wody opadowe niekorzystnych związków mineralnych. Mechaniczna uprawa gleby dna (orka) może być także w dużym stopniu pomocna w zwalczaniu nadmiernie rozwiniętej w niektórych stawach zanurzonej roślinności naczyniowej. Stawy otrzymujące zanieczyszczoną wodę bezpośrednio wymagają częstego i wyjątkowo silnego wapnowania na osuszone dno w celu zlikwidowania dużego zakwaszenia gleby (patrz kwasowość hydrolityczna — tabela V) i stabilizacji w niej żelaza i glinu. Wapnowanie przyczyni się także do uruchomienia z gleby większych ilości związków fosforowych. Ujemny wpływ nawadniania stawów tego rodzaju zanieczyszczoną wodą można także w części eliminować przez odpowiedni dobór nawozów azotowych.

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