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REMOVAL OF MICROIMPURITIES IN ARTIFICIAL INFILTRATION OF WATER

The changes of water quality have been examined in the course of its infiltration (percolation) through the soil layer. Due to application of special filters built into the bottom of infiltration pond the distribution of impurities deposited in the sediment and in soil layer has been determined.

Basing on chemical analyses of water, sediments and soil, it has been stated that during the exploitation of pond the pollutants, including organic substances and heavy metals, are partially accumulated in the sediment, which is periodically removed, and partially adsorbed in the soil, while the rest remains in the infiltrating water.

The biodegradation of the pollutants being limited, the sorption ability of the soil is gradually depleted. Consequently, the front of impurities shifts downwards in the direction of water percolation.

The investigations performed allowed to conclude that strongly polluted surface water before being introduced into infiltration pond should be subject to deep pretreatment.

1. INTRODUCTION

Technique used to production of artificial drinking surface water is frequently the subject of controversies. They can be explained by the fact that in times when infiltration areas were supplied with pure or slightly polluted surface water, and the basic task of infiltration was to remove the suspended matter and bacteria, the effects obtained were very high [1, 4, 7]. However, with the increasing pollution of surface water with chemical substances hardly or not biodegradable at all, the water obtained after infiltration process — despite its pretreatment — does not meet the standards required for drinking water [6, 8, 11, 12].

It seems probable that in the above mentioned cases initially the quality of infiltration water was not affected by the deterioration of the surface water quality and that these changes were manifested after a certain period of time. This hypothesis may be justified by the fact that after preliminary treatment (mostly by coagulation) the water contained still large amounts of inorganic and organic compounds, including microimpurities, which

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were partially adsorbed in the soil. In case of the excess of oxygen in water, only small amounts were biodegraded [6] and the remaining pollutants were adsorbed in the soil.

The subsequent inflow of pollutants resulted in saturation of sorption capacity of adsorbent (soil being on the way of the flow of infiltrating water).

Consequently, the opinion that microimpurities adsorbing in soil after saturation of their capacity may pass to the ground water seems to be justified [9].

2. THE PURPOSE OF THE INVESTIGATIONS

The purpose of the investigations was to evaluate the effects of microimpurities removal and the degree of soil pollution in the process of artificial infiltration of pretreated (by coagulation) surface water.

Considering the fact that the infiltration through ponds is the most efficient method [2], the investigations were conducted in water supply station in which this type of water treatment was used.

3. METHODS

The investigations (involving 9 series) were conducted on infiltration pond used by water supply station in Kraków, the water from the river Vistula supplied to the pond was pretreated by coagulation.

Chemical analyses of water were performed on samples of crude water from the river Vistula and infiltration pond as well as filtered through the soil layers. The analyses included also samples of soil taken from the infiltration area and the bottom sediment, deposited during exploitation. To evaluate the pollution the following substances have been determined: phenols, surfactants, pesticides, PAH, and the selected heavy metals. To complete the evaluation of the treatment process such indices as BOD_5, COD, ammonium nitrogen, and dissolved oxygen in water have been also determined.

Water samples from the pond and the neighbouring well* were taken by a bucket of Berantowicz's system, whereas the water filtered through the ground layer was taken from special testcontainers [10] installed under the pond bottom at the depths of 10, 20, 40, 60, 80, 150, and 200 cm.

To install the containers special equipment was used, owing to which natural structure of neighbouring grounds could remain intact [3].

The containers were emptied by means of a peristaltic pump, its delivery was to not exceed the amount of water flowing into containers during sampling procedure (this allowed to avoid a forced supply of containers). Each time after the exploitation cycle of the exami-

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* The well was situated at the distance of 20 m from the pond. The time of water flow through the soil layer (from the pond to well) amounted to about 100 h.

ned pond was finished, the thickness of the bottom sediment was measured. The average thickness was calculated from the measurements taken in 10 measuring points. The averaged samples of the sediment were subject to chemical analysis, the parameters determined being expressed in kg, and the total content of sediment in mg/dm^3 of the inflowing water.

In view of the fact that the ground under the bottom was highly differentiated with respect to its physical and chemical features (clayey stratification, ferrous deposits etc.) the artificial filters, the so-called colmatators (fig. 1), installed in 6 points were used in investigations of pollution degree. The colmatators made of PCV pipes of the diameter of 100 mm and height of 150 cm were filled with pure, chemically analysed sand, its grain size was similar to that of bed under the pond bottom ($d_{10} = 0.23$ mm, $d_{60} = 0.80$ mm).

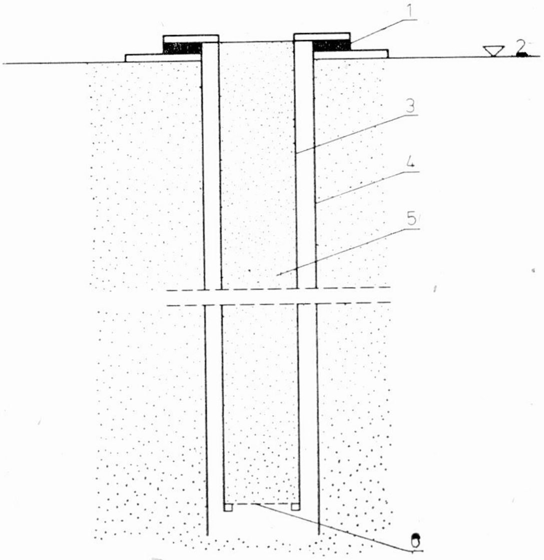


Fig. 1. Colmatator

1 – sheet rubber gasket, 2 – bottom of the pond, 3 – colmatator pipe, 4 – protective pipe, 5 – colmatator bed, 6 – protective network

Rys. 1. Kolmatator

1 – uszczelka gumowa, 2 – dno stawu, 3 – rura kolmatatora, 4 – rura osłonowa, 5 – złoże kolmatatora, 6 – siatka ochronna

To avoid wall flows the interior walls of the colmatators were strongly matted. Lower outlets of the colmatators were protected with flanges and steelon gauze (mesh sizes 150 × 150 μm) to prevent the washing out of the sand. Colmatators were placed in protective PVC pipes (⌀ 150 mm), installed in boreholes and arranged in two rows along the pond axis. The contact between the colmatator edge and protecting pipe was tightened with a sheet rubber gasket. The colmatators being placed in protecting pipes could be easily taken out for sampling and then put again.

For chemical analysis the samples of bottom sediment and sand bed were taken from the colmatator at the depths of 10, 20, 30, 40, 60, 80, 100, and 150 cm. To this end the colmatator was previously taken out from the protecting pipe and cut longitudinally. The contents of the separate pollutants were determined for 100 g of bed or sediment.

4. RESULTS OF INVESTIGATIONS

4.1. WATER QUALITY

Crude water taken from the river appeared to be highly polluted. After coagulation and several hour residence in settling tank the pollution only slightly decreased. Extreme values of the parameters examined and characterizing the quality of crude water from the river Vistula delivered to infiltration pond after coagulation are given in tab. 1.

Table 1

Extreme values of the selected indicators of quality of water taken from the river Vistula and infiltration pond

Ekstremalne wartości wybranych wskaźników jakości wody z Wisły oraz stawu infiltracyjnego

Kind of index	Units	Concentration			
		the river Vistula		pond	
		minimal	maximal	minimal	maximal
Temperature	°C	4	24.4	4	27
Dissolved oxygen	mg O_2/dm^3	2.8	10.5	8.2	14.0
BOD_5	mg O_2/dm^3	3.4	9.9	1.8	7.2
COD ($K_2Cr_2O_7$)	mg O_2/dm^3	26.3	50.0	15.8	38.5
$N\text{-}NH_3$	mg/dm^3	0.4	8.0	0.15	1.8
Cu	mg/dm^3	0.012	0.25	0.008	0.25
Zn	mg/dm^3	0.06	1.2	0.6	0.8
Pb	mg/dm^3	nd*	0.2	nd	0.03
Cd	mg/dm^3	0.002	0.014	nd	0.07
Ni	mg/dm^3	0.01	0.08	0.01	0.12
Cr^{+6}	mg/dm^3	nd	0.16	nd	0.16
Phenols	mg/dm^3	nd	0.12	nd	0.3
Surfactants	mg/dm^3	nd	1.0	0.14	0.26
Pesticides	mg/dm^3	nd	0.0035	nd	0.0035
PAH	$\mu g/dm^3$	—	—	0.28	0.69

* not determined.

4.2. CHARACTERISTICS OF THE POND

The pond is an irregular tetragone of the total area of 3700 m^2. The water level varies from 170 mm to 190 mm and is controlled by a gate valve installed on the delivery pipe. The efficiency of pond ranges within 1.0-0.15 $m^3/m^2/d$. When the capacity drops below 0.15 $m^3/m^2/d$ — the pond is out of operation and subject to cleaning.

From grain size analysis of the ground taken down to the depth of 150 cm under the pond bottom it follows that surface layer (20 cm) is formed by sand $d_{10} = 0.23$ mm, $d_{80} = 0.7$ mm and below by sand $d_{10} = 0.15 - d_{80} = 0.40$ mm.

4.3. VARIATIONS IN WATER POLLUTION INDICATORS DURING INFILTRATION OF WATER THROUGH THE INFILTRATION POND

The investigations (9 series) were conducted from March 1974 till October 1976. In two first series the water was sampled from the pond, all test containers and from two nearest wells. In the third series the water samples were taken from the pond, wells and test containers placed at the depths of 60, 150 and 200 cm (the sampling from the remaining test containers failed). In series VII and VIII filtered water was sampled from the containers placed at the depths of 20, 40, 60, and 150 cm. In the remaining cycles the analysis included solely the water from infiltration pond and wells. Because of high differences in initial concentrations, results are presented in percent with respect to the concentrations in pond assumed to be 100%. Since unexpected increments of some indices have been stated in some samples (probably due to the varying feeding area of the containers) the results obtained were averaged.

The averaged values of the separate indicators allowed to present graphically the removal of individual pollutants.

While analyzing the changes in ammonia concentration occurring in the vertical section it can be stated that the process of ammonia oxidation is temperature dependent (fig. 2a). At water temperature higher than 10°C the oxidation proceeds chiefly in the upper bed layer and stops at the depth of 200 cm, while at temperature lower than 10°C this process proceeds efficiently only in layers deeper than 100 cm. It seems that the efficiency of this process is connected with the fact that the water must be heated up to the temperature at which the oxidation rate is sufficiently high. The increase of water temperature during its infiltration through the bed results from the heat exchange with sand heated during summer [8].

The removal of other compounds subject to biological reconstruction (fig. 2b) follows similar course. At temperature higher than 10°C, the BOD_5 of water infiltrating through 100 cm bed layer decreases by about 75% and remains unchanged. If, however, this temperature is lower than 10°C the effect of biodegradation is lower and amounts to 50%. Contrary to the previous case the process does not end at the near surface layer of the bed, where BOD_5 decreases by 40% but it proceeds, though less efficiently, in deeper layers.

The changes in oxygen concentration in water are distinctly correlated with the oxydation of ammonia and biodegradation of organic compounds (fig. 2c). At water temperatures higher than 10°C oxygen consumption drops by about 80% of the initial concentration, whereas at temperatures below 10°C oxygen content decreases by about 50%.

It is worth noticing that the decrease of oxygen content in water observed at temperatures higher than 10°C takes place chiefly in the near surface (200 cm) bed layer, and that at temperatures below 10°C oxygen consumption is observed within the whole depth of the bed — from the bottom of the pond to the well.

The COD decreased during the infiltration by about 35% (fig. 2d) independently of DO concentration and temperature of water. From the analysis of the changes in COD

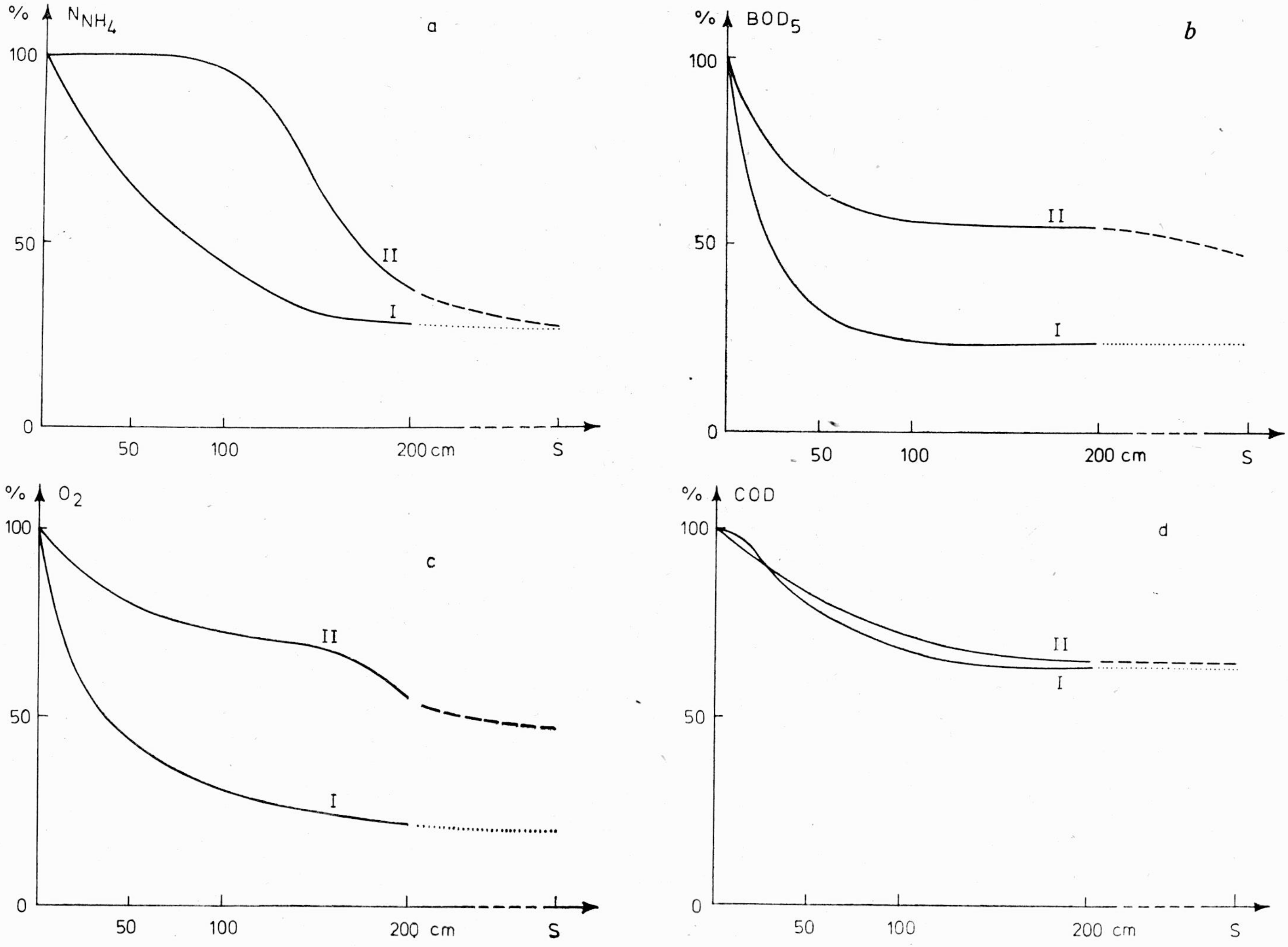


Fig. 2a, b, c, d. Changes of the selected indicators of water quality during infiltration through the ground layer under the infiltration pond

Rys. 2a, b, c, d. Zmiany wybranych wskaźników jakości wody w procesie jej przesiąkania przez warstwę

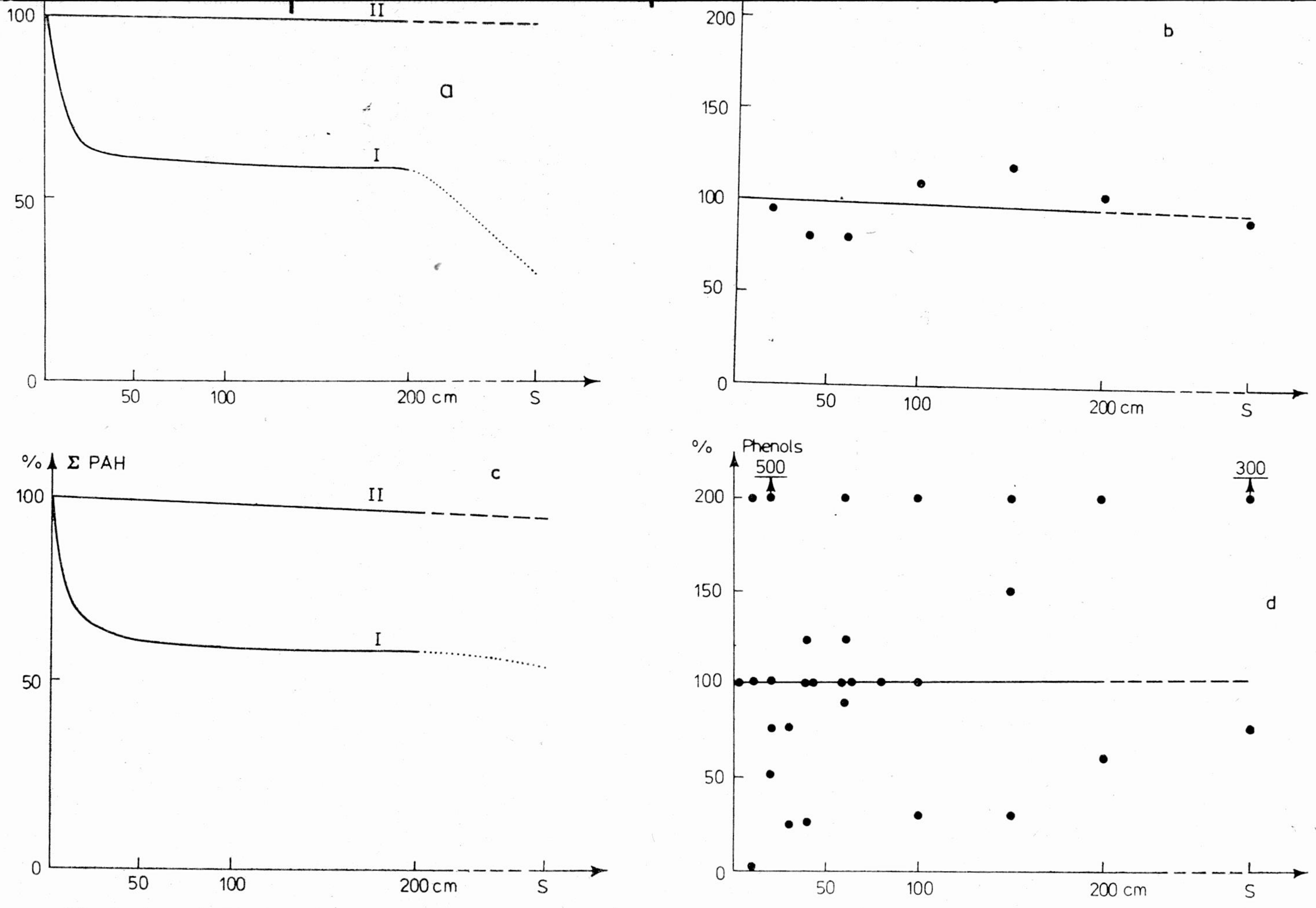


Fig. 3a, b, c, d. Changes in organic microimpurities during infiltration of water through ground layers under the infiltration pond
Rys. 3a, b, c, d. Zmiany stężenia mikrozanieczyszczeń organicznych w procesie przesiąkania wody przez warstwę gruntu pod stawem infiltracyjnym

of water and taking account of the stated temperature dependence of BOD_5 removal it may be inferred that each indicator represents different chemical compound.

The fact that the removal of COD is independent of temperature allows to infer that most organic compounds are removed in the infiltration process chiefly by sorption, which proceeds most intensely in the near surface (150 cm) layer of the bed under the pond bottom.

While analyzing the infiltration effect in removal of organic microimpurities it may be stated that for the concentrations examined the efficiency of this process is rather small and depends on the kind of compounds being removed.

If the initial concentration of pesticides in water amounted to 0.0035 mg/dm^3, then after the infiltration through the 50 cm layer of the bed their concentration decreased by 35% and down the way to well by additional 35% (series I, fig. 3a), while at the initial concentration of 0.002 mg/dm^3 no further decrease was stated (series II, fig. 3a).

Phenol concentrations in water taken from test containers very often exceeded those in the infiltration pond water. High and random dispersion of results (fig. 3d) did not allow to calculate the mean values. It seems, however, that phenols are not retained in the bed during infiltration of water, and their increased concentration may be due to product of humus compounds biodegradation [5].

From the analysis of the changes in the contents of surfactants in water taken in vertical section of the bed and in well (fig. 3b) it may be stated that within the range of concentrations lower than 0.4 mg/dm^3 removal due to infiltration is insignificant.

PAH removal follows an entirely different course. These compounds are removed from water mostly after its infiltration through the first 10 cm layer of the bed (fig. 3c). This effect depends, however, on concentration since in case of 0.28 μg/dm^3 of PAH (series II) only 5% of these compounds was removed. It should be added that the percentage of the separate PAH in their total content was in both cases quite similar. Considering the fact that the efficiency of PAH removal was temperature independent, it seems probable that these compounds are resistant to biodegradation.

The degree of heavy metals removal in infiltration process was rather low, it also seems that this effect depended on the kind of metal as well as on its concentration.

Cadmium and lead in concentrations lower than 0.1 mg/dm^3 were only slightly retained in the upper 50-60 cm layer of the bed, and after infiltration through a 200 cm layer their concentrations in water decreased by 15-20% (figs. 4a and 4b).

The removal efficiency of copper and nickel whose maximum concentrations in pond water range within 0.01-0.015 mg/dm^3 was somewhat higher amounting to 20-30% (figs. 4c and 4d).

It should be mentioned, however, that in all the cases the removal of heavy metals has been stated only in 200 cm layer of the bed, in well their concentrations in many cases exceeded the initial ones. It may be probably explained by the fact that due to about 5 day flow of the water from the pond bottom to the well the samples taken corresponded to a different quality of raw water.

No decrease in the concentration of zinc in water after infiltration has been stated if the initial content of this element was lower than 0.6 mg/dm^3. On the contrary, very often

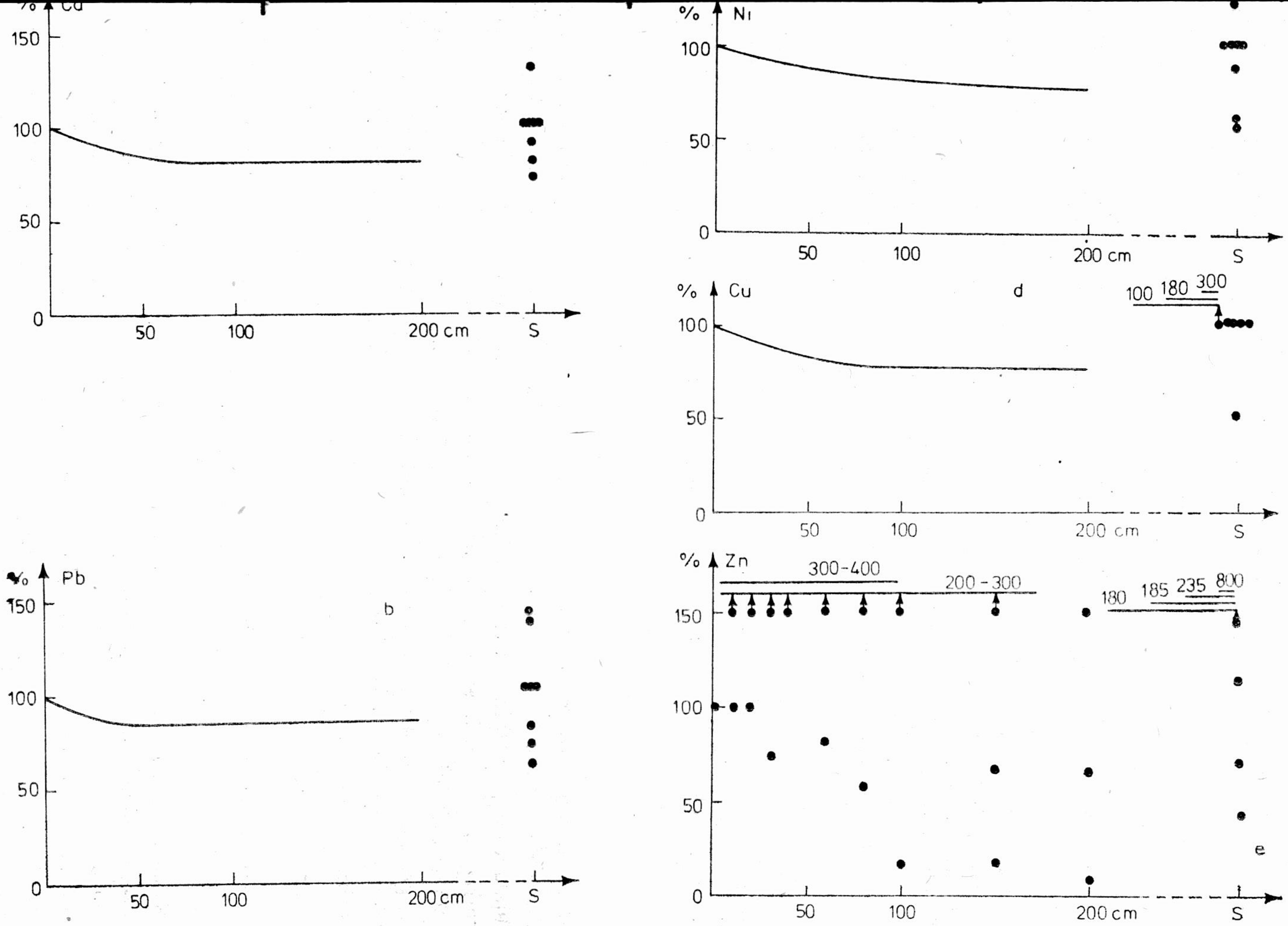


Fig. 4a, b, c, d, e. Changes in concentrations of heavy metals during infiltration of water through the ground layer under the infiltration pond
Rys. 4a, b, c, d, e. Zmiany stężenia metali ciężkich w procesie przesiąkania wody przez warstwę gruntu pod stawem infiltracyjnym

Concentrations of microimpurities in bottom sediments
Zawartość mikrozanieczyszczeń w osadach dennych stawu

		Parameters						
Series	Unit	COD O_2	BOD_5 O_2	Extract of ether	Phenols	Surfactants	Pesticides	Cr
I	kg in the total sediment volume	56.4	3.2	1.8	nd*	0.2	nd	nd
	mg/dm³ of filtrated water	0.46	0.026	0.015	nd	0.0016	nd	nd
II	kg in the total sediment volume	619.0	2.92	nd	nd	0.06	0.0018	0.25
	mg/dm³ of filtrated water	5.0	0.024	nd	nd	4.8×10^{-4}	1.5×10^{-5}	0.002
III	kg in the total sediment volume	606	nd	2.8	nd	0.05	0.0018	0.53
	mg/dm³ of filtrated water	3.87	nd	0.018	nd	3.2×10^{-4}	1.1×10^{-5}	0.003

nd* – not determined.

in the water taken from measuring boxes installed in bed the concentrations of zinc were higher than in pond (fig. 4e). This phenomenon results probably from the fact that zinc compounds deposited in bed are dissolved due to the decreasing pH of infiltrating water occurring in case of intense oxidation of organic compounds.

While estimating the efficiency of chromates removal it should be emphasized that their presence in water infiltration has been stated only in one case (in concentration of 0.008 mg/dm³). It seems that chromates were reduced during infiltration through the layer of sediment settled on the bottom of the pond.

4.3. IMPURITIES DEPOSITED IN THE SEDIMENT AND IN SAND UNDER THE BOTTOM OF THE POND

Results of the III series of investigations are presented in tab. 2. From the analysis of results presented in tab. 2 it follows that — despite the differences in operation times and amounts of water filtered, the layer thicknesses of the sediments deposited on the bottom in separate cycles are very similar. This fact allows to infer that the pond efficiency during investigation depended on the amounts of suspended matter introduced with water and characterized by similar filtering ability.

Table 2

of infiltration pond in 3 selected experimental cycles
infiltracyjnego w wybranych trzech cyklach eksploatacyjnych

Parameters									
Pb	Cu	Cd	Zn	Ni	PAH	Time of cycle [days]	Thickness of sediment [mm]	Volume of sediment [m^3]	Amounts of filtered water [m^3]
0.2	0.07	nd	7.3	0.4	nd	48	8	29.36	123360
0.0016	5.7×10^{-4}	nd	0.059	0.0032	nd				
1.1	0.5	0.15	1.2	0.6	0.000021	48	7	25.69	123360
0.009	0.004	0.0012	0.01	0.005	1.7×10^{-7}				
0.7	0.18	0.11	2.8	0.53	nd	61	8	29.36	156770
0.0045	0.001	0.0007	0.056	0.003	nd				

On the other hand, the comparison of COD values indicates large differences in the chemical composition of sediments. The sediment taken from the bottom of the pond in cycle I contained about 10 times smaller amounts of organic pollutants oxidized with potassium biochromates than the sediments taken after the cycles II and III. The contents of chemical compounds oxidized biologically were, in contrary, similar as it follows from the the values of BOD$_5$. Analogically, the contents of organic substances extracted by petroleum benzin were also similar.

From the comparison of the amounts of the mentioned above organic pollutants, deposited in sediment and calculated for the unit volume of the water filtrated with their extreme concentrations in water introduced to the pond (tab. 1), it may be inferred that in the sediment these pollutants are only slightly cumulated. A similar analysis performed for the concentrations of surfactants, pesticides and heavy metals shows that the effect of their cumulation in the sediment is also small. In case of PAH the cumulation is probably higher, but in view of the fact that these investigations were performed in one series only — the results obtained cannot be considered as representative ones.

The pollution degree of sand bed in colmatators was examined in series V. Exposition time of colmatators was different and ranged from 63 to 617 days.

To perform a qualitative analysis of the distribution of pollutants in vertical section of the colmatator beds it should be assumed that in sediment–sand interface (boundary) the concentration of organic substances determined by COD decreases rapidly, and further changes in concentrations have a linear character. Assuming for simplification that the distribution in the near surface layer (0-10 cm) proceeds in a way similar as in the underlying layer (10-20 cm) the changes in concentrations of the mentioned pollutants in vertical section of sand bed have been presented graphically in form of curves shown in fig. 5. The mean concentrations of COD, taken from the graph, allowed to calculate

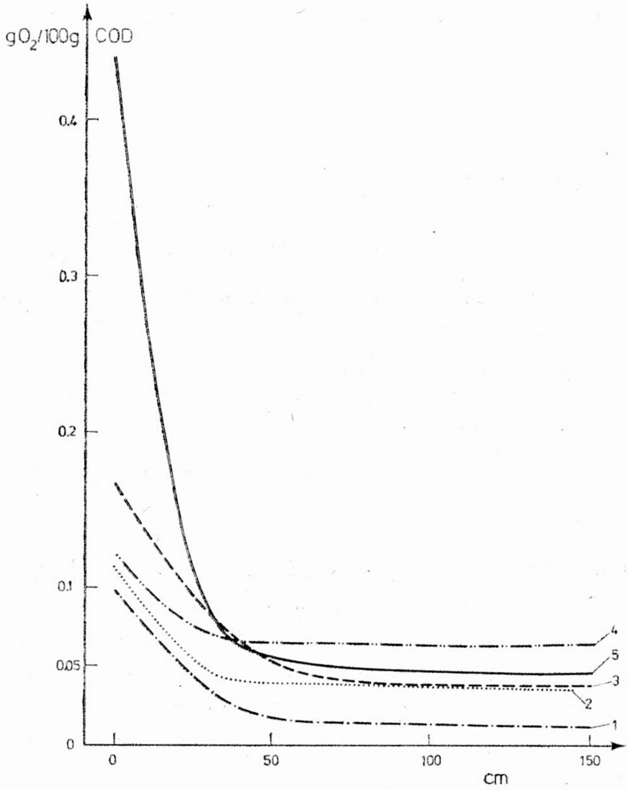


Fig. 5. Concentration and distribution of organic substances in vertical section of colmatator beds 1-5 — series

Rys. 5. Stężenie i dystrybucja substancji organicznych w przekroju pionowym złóż kolmatatorów 1-5 — serie

weight percentage of organic substances in separate layers of the bed and in sediments deposited on the surface. The distribution of pollutants in vertical section has been also calculated (in percent). Density of bed and sediment assumed for calculations amounted to 2 g/cm^3. Results are presented in tab. 3.

From the analysis of the penetration depth of organic substances in series II and III (basing on tab. 3) in which in spite of a similar thickness of sediment layers the distribution of concentrations in vertical section was different, it may be inferred that the sorption

Table 3

Concentrations and mean contents (in g) of organic substances determined as COD in sediments and separate layers of the filter bed

Stężenia oraz średnie zawartości wagowe substancji organicznych oznaczonych jako ChZT w osadzie i w poszczególnych warstwach złoża

Series / Exposition time	Depth of sediment sampling in vertical section [cm]	COD [g O_2/100 g]	Layer [cm]	Mean content [g]	% of total pollution
I 67 5.10.1974 - 11.12.1974		1.720	0.8	4.86	24.8
	10	0.070	0 - 10	3.04	15.5
	20	0.059	10 - 20	2.26	11.5
	30	0.047	20 - 30	1.66	8.5
	40	0.022	30 - 40	1.06	5.4
	60	0.017	40 - 60	1.34	6.8
	80	0.017	60 - 80	1.20	6.1
	100	0.017	80 - 100	1.20	6.1
	150	0.017	100 - 150	3.00	15.3
II 93 1.08.1974 - 11.12.1974		4.31	1.2	18.26	41.6
	10	0.086	0 - 10	3.53	8.1
	20	0.063	10 - 20	2.68	6.1
	30	0.047	20 - 30	1.94	4.4
	40	0.042	30 - 40	1.55	3.5
	60	0.041	40 - 60	2.89	6.6
	80	0.041	60 - 80	2.89	6.6
	100	0.041	80 - 100	2.89	6.6
	150	0.041	100 - 150	7.24	16.5
III 257 12.12.1974 - 26.08.1975		1.3	1.3	5.97	15.7
	10	0.136	0 - 10	5.30	13.9
	30	0.087	10 - 30	7.55	19.8
	60	0.047	30 - 60	6.35	16.6
	100	0.04	60 - 100	5.93	15.5
	150	0.04	100 - 150	7.06	18.5
IV 280 1.09.1975 - 9.06.1976		3.8	1.7	22.80	37.2
	10	0.097	0 - 10	3.88	6.3
	20	0.085	10 - 20	3.18	5.2
	30	0.076	20 - 30	2.68	4.4
	60	0.068	30 - 60	7.20	11.8
	100	0.065	60 - 100	9.25	15.2
	150	0.069	100 - 150	12.18	19.9
V 617 12.12.1974 - 20.08.1974		4.1	3.3	47.82	50.7
	10	0.30	0 - 10	12.00	12.7
	20	0.16	10 - 20	7.41	7.9
	30	0.075	20 - 30	4.38	4.6
	60	0.055	30 - 60	6.78	7.2
	100	0.50	60 - 100	7.06	7.5
	150	0.50	100 - 150	8.82	9.4

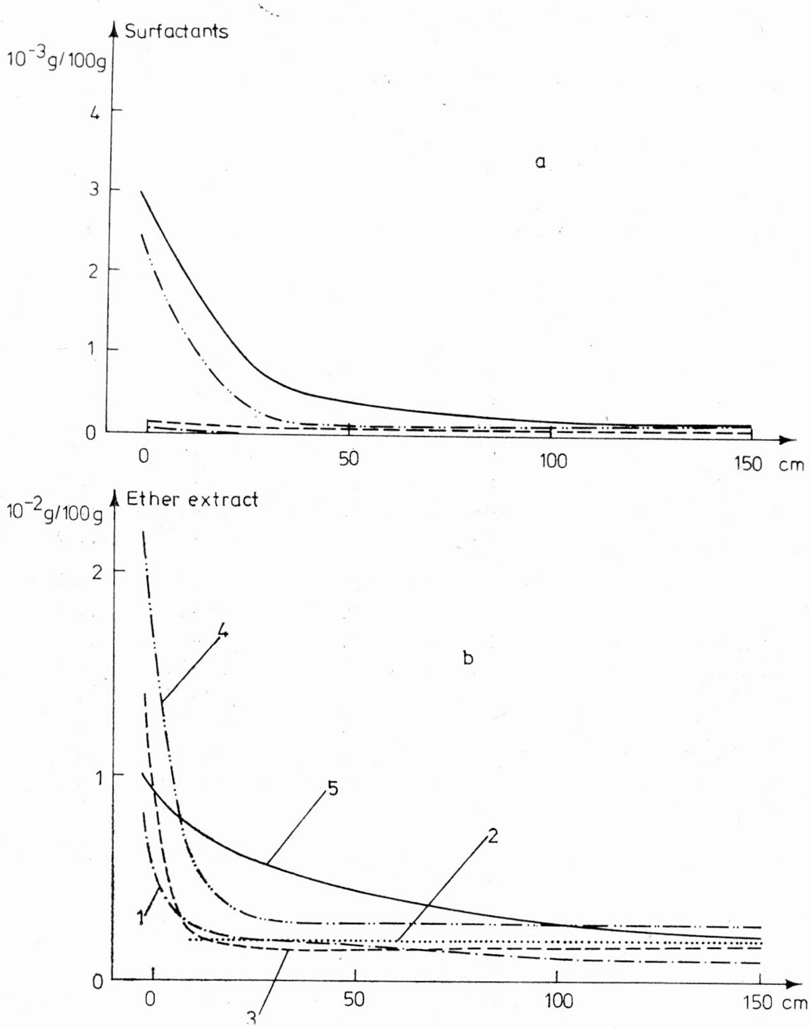


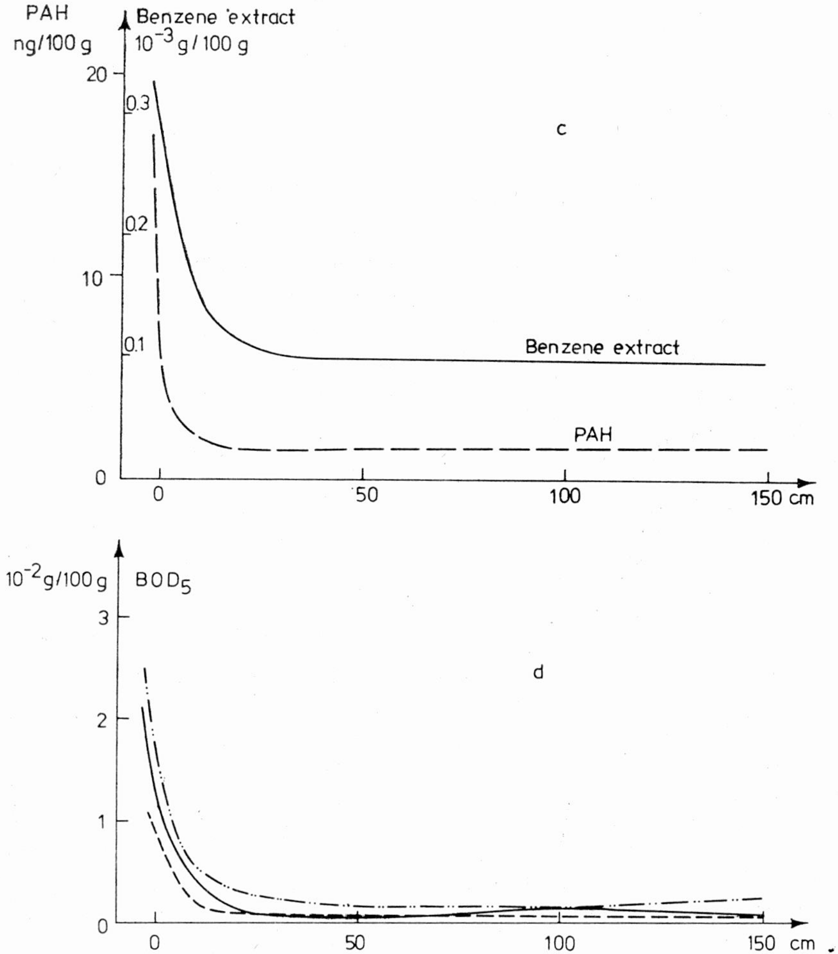
Fig. 6a, b, c, d. Concentration and distribution of microimpurities and biodegradable substances in vertical cross-section of colmatator beds

1-5 — series

intensity of organic substance in bed depends on the quality of water subjected to infiltration and on physical properties and chemical composition of sediment deposited on the pond bottom surface.

From the values of COD stated in various experimental series it follows that the sediment in series II was characterized by large amounts of organics, while in series III mineral compounds prevailed.

Despite a high infiltration efficiency of the bottom sediment layer a part of organic substances passes to and is sorbed inside the sandy bed. As it may be seen from the results in tab. 3, the concentration distribution in the bed is not uniform and that the near bottom



Rys. 6a, b, c, d. Stężenie i dystrybucja mikrozanieczyszczeń oraz substancji podlegających biodegradacji w przekroju pionowym złóż kolmatatorów

1-5 — serie

layer (0-10 cm) plays an important role, since the increment of organics is the highest there. With the depletion of sorption capacity occurring in upper bed layers the front of pollutants shifts down. This process may be seen when comparing the curves in fig. 5.

Assuming that during a normal work the cycle of the pond operation does not exceed 90 days [3] it may be stated that in the case examined most organic substances were removed in infiltration process. About 40% of substances retained in infiltration of pollutants was deposited in the bottom sediment, the remaining ones were sorbed on the sand bed grains.

Considering the fact that no dependence was stated between the temperature and the effect of COD decrease, which may prove that microorganisms do not participate in the

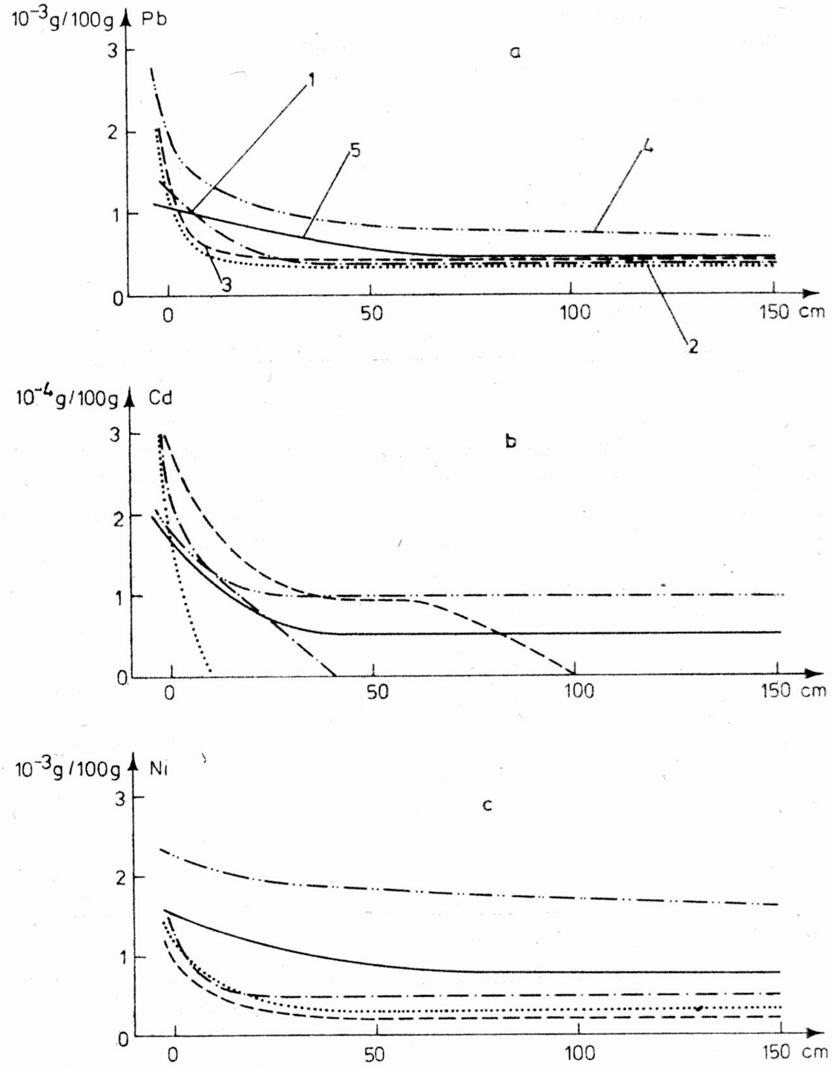
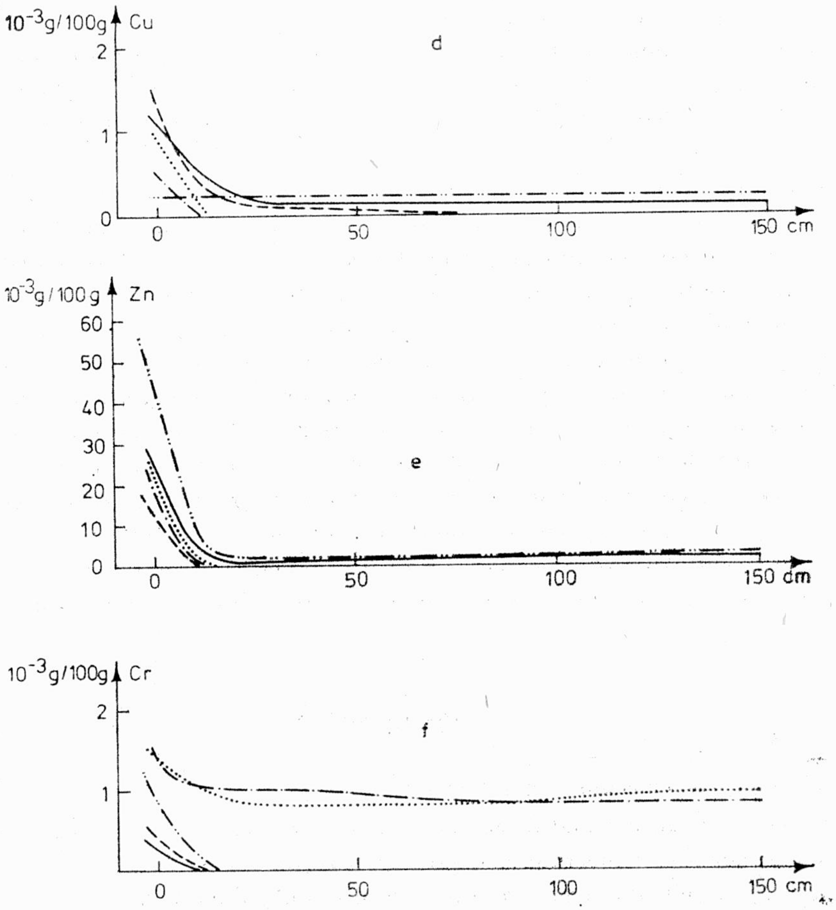


Fig. 7a, b, c, d, e, f. Concentration and distribution of heavy metals in vertical section of colmatator beds 1-5 — series

process of water purification, a progressive pollution of bed and, after saturation of its capacity, the penetration of pollutants to the well may be expected.

The described mechanism, according to which the front of organic pollutants shifts inside the sand bed with the time of exposition, has been confirmed for the case of surfactants and substances extracted with ether (fig. 6a, b).

A gradual increase of bed pollution with PAH and the substances extracted with benzene follows probably the same mechanism. Since, however, the respective substances were determined in only one series, this hypothesis could not be verified experimentally.



Rys. 7a, b, c, d, e, f. Stężenie i dystrybucja metali ciężkich w przekroju pionowym złóż kolmatatorów
1-5 — serie

It seems worthy noticing that small amounts of surfactants are accumulated in the bottom sediment, the effect of which is similar to that of sand bed layers lying below. It should be, moreover, stated that the amount of surfactants adsorbed in sediment and bed is very small, these results being distinctly correlated with the results obtained from water samples analyses.

The distribution of PAH concentrations in bed (fig. 6c) is also consistent with the fact of their removal, chiefly in sediment and the surface layer of the bed, and stated in water analyses.

BOD_5 concentration decreases at the exposition time of colmatator prolonged to 617 days (series V). This was probably due to higher efficiency of filtration through a thick bottom sediment layer (fig. 6d). This effect corresponded to the process of biodegradation of organic compounds deposited earlier to the bottom sediment and contributed to the production of carbon dioxide which lowered the pH of the flowing water. It seems that due to the last effect some metals, adsorbed earlier in the bed, were washed out. This relationship is particularly well seen while comparing the contents of Cd, Ni, Pb in series IV and V (fig. 7a, b, c). Not so strong correlation has been observed for Cu and Zn (fig. 7d, e).

As far as the removal of heavy metals is concerned, the graphs 7a-e allow to state that the vertical distribution of these metals in sand bed is not uniform. Zn and Cu are mostly removed in bottom sediment, while Pb, Cd and Ni are also accumulated in the bed. The gradual shift of the pollutants front down the bed, observed earlier in case of organic compounds, has been also stated for heavy metals.

Chromium removal followed a different course. It probably was present in water in form of chromates (fig. 7f). In cycles I and II, when on the colmatator bed there was no sediment at all its layer was very thick, chromates deeply penetrated into the bed. It seems probable that with the prolongation time of colmatators exposition, part of chromates were reduced by organic compounds introduced into the bed, and part of them were washed out. Supposingly this process depended on the quality of water let into the pond and kind of bottom sediment. After the sediment was thickened and its layer increased the chromates were there reduced and only a small amount passed with water into deeper layers of the bed.

5. CONCLUSIONS

The following conclusions can be drawn:

1. Chemical oxygen demand decreases some tens percent during infiltration and this effect is independent of temperature. A great part of these compounds is retained in the bottom sediment, while the remaining was sorbed in the ground or migrate with the infiltrating water. With the depletion of sorption capacities of the separate layers, the front of impurities shifts inside the ground.

2. Biodegradation of organic compounds subject to biodegradation and oxidation of ammonia occurs chiefly in the bottom sediment and in the upper near surface layer of the ground under the bottom. When the oxygen content is sufficiently high the efficiency of this processes is closely temperature-dependent. Hence, in Polish climatic conditions the rate of these process is lower from late autumn to the early spring.

3. The efficiency of removal of organic microimpurities depends probably on their solubility in water and on concentration. About 50% of PAH and other pesticides are deposited in the bottom sediment and ground, while surfactants are only slightly accumulated and they mostly migrate to ground waters. Phenols are not removed, on the contrary, being the products of biodegradation of humus compounds their concentrations may sometimes increase. It may be stated, in general, that during operation of pond the front of microimpurities present in the ground shifts continueously according to water infiltration.

4. Heavy metals are removed from water only partially, and this effect depends of the kind of metal and its concentration in water subject to infiltration. Like in case of organic microimpurities with the prolonged exploitation of the pond, the front of heavy metals shifts gradually inside the ground. In case of a particularly intense biodegradation of organic compounds, heavy metals may be evaluated from the ground to the infiltration water, thus contributing to its secondary pollution. This phenomenon is probably due to the increasing thickness of the bottom sediment deposited at prolonged exploitation cycles.

Finally, it is concluded that strongly polluted surface waters should be pretreated before being introduced to the infiltration pond. The kind of pretreatment (coagulation, adsorption on activated carbon) depends on the kind and amount of pollutants.

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ELIMINACJA MIKROZANIECZYSZCZEŃ W PROCESIE SZTUCZNEJ INFILTRACJI WODY

Przeprowadzono badanie zmian jakości wody w procesie jej przesiąkania przez warstwę gruntu. Stosując specjalne filtry, wbudowane w dno stawu infiltracyjnego, określono dystrybucję zanieczyszczeń w odkładającym się osadzie oraz w warstwie gruntu.

Na podstawie analiz chemicznych wody, osadów i gruntu stwierdzono, że w procesie eksploatacji stawu zanieczyszczenia, w tym mikrozanieczyszczenia organiczne oraz metale ciężkie, częściowo gromadzą

się w osadzie, który okresowo jest usuwany, częściowo adsorbują się w gruncie, a reszta pozostaje w przesiąkającej wodzie.

W związku z ograniczoną biodegradacją wprowadzanych zanieczyszczeń zdolność sorpcyjna gruntu stopniowo ulega wyczerpaniu i w efekcie tego front zanieczyszczeń przesuwa się w głąb, zgodnie z kierunkiem przemieszczania się wody.

Przeprowadzone badania pozwoliły na wyrażenie poglądu, że w przypadkach silnie zanieczyszczonych wód powierzchniowych przed wprowadzeniem na stawy infiltracyjne konieczne jest ich zaawansowane wstępne uzdatnianie.

ELIMINIERUNG VON MIKROVERUNREINIGUNGEN WÄHREND KÜNSTLICHER GRUNDWASSERANREICHERUNG

Untersucht wurde die Veränderung der Wasserbeschaffenheit während einer Bodenversickerung.

In den Boden eines Sickerteichs wurde ein Testfilter eingebaut. In diesem Filter konnte man die Verteilung der Schmutzstoffe auf Schlamm und Boden verfolgen. Anhand von chemischen Analysen des Wassers, der Schlämme und des Bodens stellte man fest, daß während des Betriebs der Teichanlage, ein Teil der Schmutzstoffe (darunter Schwermetalle) im Schlamm verbleibt (welcher von Zeit zu Zeit ausgetragen wird), ein Teil wird im Boden adsorbiert und der Rest ist im durchgesickerten Wasser gefunden worden.

Der biochemische Abbau der zugeführten Schmutzstoffe ist begrenzt, die Sorptionsfähigkeit des Bodens erschöpft sich ebenfalls mit der Zeit und dies zieht eine ständige Verschiebung der Schmutzfront immer mehr in die Tiefe nach sich, gemäß der Fließrichtung des Wassers.

Ein stark verschmutztes Oberflächenwasser muß vor der Zuführung zu Sickerteichen zwecks Anreicherung des Grundwassers unbedingt vorgereinigt werden.

ИСКЛЮЧЕНИЕ МИКРОЗАГРЯЗНЕНИЙ В ПРОЦЕССЕ ИСКУССТВЕННОЙ ИНФИЛЬТРАЦИИ ВОДЫ

Было проведено исследование изменений качества воды в процессе её просачивания сквозь слой грунта. Применяя специальные фильтры, встроенные в дно инфильтрационного пруда, было определено распределение загрязнений в откладывающемся осадке, а также в слое грунта.

На основе химических анализов воды, осадков и грунта было отмечено, что в процессе эксплуатации пруда, загрязнения, в том числе и органические микрозагрязнения, а также тяжёлые металлы частично скапливаются в осадке, который периодически удаляется, частично адсорбируется в грунте, а остаток остаётся в просачивающейся воде.

В связи с ограниченной биодеградацией вводимых загрязнений сорбционная способность грунта постепенно подвергается исчерпанию и в эффекте этого фронт загрязнений перемещается вглубь, соответственно с направлением перемещения воды.

Проведенные исследования позволили выразить мнение, что в случаях сильно загрязнённых поверхностных вод, до подвода к инфильтрационным прудам, необходимым является глубокая их обработка.