

KAZIMIERZ PASTERNAK

Wpływ zanieczyszczeń huty cynku w Miasteczku Śląskim na zawartość mikroelementów w środowisku wód powierzchniowych***The influence of the pollution of a zinc plant at Miasteczko Śląskie on the content of microelements in the environment of surface waters**

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Abstract—The level of the concentration of microelements and their accumulation and distribution were determined in the water and sediments of rivers, streams, and reservoirs in the region of zinc and lead smelting works. It was found that already in the first period of the activity of such industries the state of purity of neighbouring surface waters is affected not only by the release of wastes but also by the pollution of the air. The occurrence of heavy metals in the waters and sediments was considered against the background of their basic properties and of the general pollution situation of the region. The release of metallurgical waste waters brings about a very great increase in the amount of Zn, Cd, and Pb in the main river of the investigated territory. An exceptionally high content of cadmium occurs in the water of this river, which among other factors decreases the class of purity of this river. In the investigated water system the degree of distribution of metals, especially of Zn, is very high. The reservoirs on this river favour the self-purification of the water from the metals.

The plants of the smelting industry, particularly of non-ferrous metals, may in various ways have a negative influence not only on the quality of the air, the chemism of soils, and the vegetation in the nearest vicinity (Skawina, Wąchalewski 1965, Skawina 1967, Greszta, Godzik 1969, Paluch, Karweta 1970, Kowaliński et al. 1972, Turski, Baran 1972) but also on the neighbouring aquatic environments (Skei et al. 1972, Winchester, Nifong 1973, Pasternak, Gliński 1972, Pasternak 1973). The intensity of the influence of metallurgical pollution on surface waters depends in a great measure on the degree of sewage purification, on the technological processes of a given plant, and on the time of its production activity. This intensity may show greater or less variability in space. In general, considerable pollution of head water occurs only in that part of the grounds surrounding the plant where the wastes are directly released and strong fallout of industrial dusts (from the air and from the dumps of dust wastes) are recorded. In the vicinity

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of industrial works the level and the process of the contamination with various compounds of the waters in further zones, which remain within the range of emitted dusts only or under the influence of polluted ground waters, may be different (Robbins et al. 1973, Golwer, Schneider 1973). It seems that the pollution of waters in these zones will in an exceptionally great degree depend not only on the intensity of the emission of dusts but also on the time of the activity of a plant and from the character of the catchment area whence these waters flow. In the case of the territories which were the subject of the present investigations, the influence of the ground waters on the chemism of surface waters would probably be of secondary importance, since in this region, in consequence of considerable drawing up of ground waters by numerous artesian wells for the water supply of the metallurgical works "Miasteczko Śląskie", the waterworks "Biliela", and other industrial objects (to the amount of 4110 cu. m. of water/hr), the circulation of the ground waters in the direction of the river is slightly disturbed and retarded.

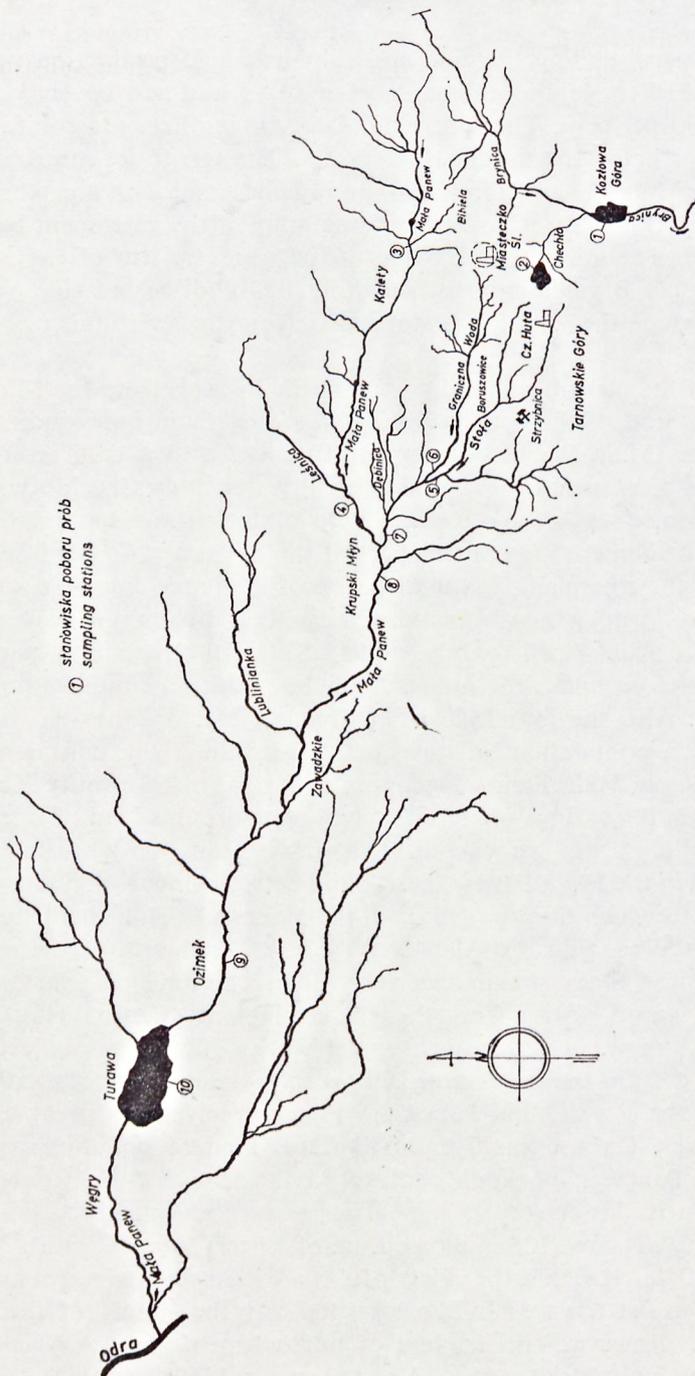
Heavy metals form a significant percentage of pollution penetrating from zinc and lead works to the biological environments. Great amounts of them occur both in the sewage (Jennet, Wixson 1972, Pasternak 1973) and in the emitted dusts (Skawina, Wąchalewski 1965, Winchester, Nifong 1973). The content, distribution, and accumulation of heavy metals in the aquatic environments situated in the vicinity of this kind of metallurgical works are little known in our country. Particularly little is known about the range of the influence of dusts, emitted into the air by zinc and lead smelting works, on the content of heavy metals in the water. As is known, all these problems are important since higher contents of heavy metals in the water can influence unfavourably not only the clean but also the polluted waters (i.e. the aquatic organisms which take part in their pollution, Zajączkowska-Stęplowska 1972).

The aim of the present work was to obtain further data on the level of the concentration, migration, and cumulation of heavy metals in the environment of surface waters in the neighbourhood of zinc plants. On the example of the vicinity of zinc and lead smelting works in the town of Miasteczko Śląskie it was above all attempted to determine whether in the first period of the production activity of such plants the influence of the emitted dusts on the chemism of the water and of bottom sediments of the neighbouring rivers and water reservoirs situated on the lines of the prevailing winds, is already visible, the zinc plant "Miasteczko Śląskie" having been built on so far non-industrialized territories (forests, arable land) and the initial sectors of the neighbouring rivers do not receive any fluid pollution. In this territory only the local drawing up of the ground waters and a slight contamination of the air are not quite new phenomena. Moreover, it should be noted that the dam reservoir on the River Brynica (Kozłowa Góra) is utilized for waterworks.

Territory of investigations

The territories surrounding the zinc and sulphuric acid production works "Miasteczko Śląskie" have the character of a plain and are covered with forests to about 70 per cent. The forest stands occurring here are coniferous monocultures, pine being the dominating species. The territories are drained by two rivers, the Mała Panew (about 120 km in length and with a catchment area of 2037 sq. km.) and Brynica. The physiography of the catchment basins of these two rivers is similar. The scheme of the water system of the Mała Panew and the upper Brynica is presented in fig. 1, the discussed zinc works and the stations where the samples of water and sediments were taken, being marked there.

The receiver of the neutralized and partly purified wastes from the Miasteczko Śląskie plant and of the usually untreated wastes from other industrial works is the River Mała Panew. The upper Brynica, with a dam reservoir at Kozłowa Góra constructed on it, and a small water body Chechło within its catchment basin, does not receive any fluid pollution and has relatively clean water. The catchment area of this part of the Brynica is situated on the windward side of the zinc plant, in the direction of the prevailing west winds. In the investigated territory the west winds change their direction to NW most often in the period from April to July, and to SW in the remaining part of the year. It is therefore under the influence of the pollution emitted into the air by the works. Also the initial clean sector of the Mała Panew is within the range of only a poor fallout of dusts emitted by the plant, considerable pollution of the River Mała Panew beginning as far as in the locality Kalety (24 kilometres from the spring) where it receives an enormous load of organic wastes from a cellulose and paper-mill. The wastes from the zinc smelting plant are released to the Mała Panew several kilometres below Kalety through the Stoła stream, to which they are led from the plant through a small stream (canal) Graniczna Woda (fig. 1). Already far above the mouth of the canal Graniczna Woda the Stoła stream receives a load of municipal wastes, of strongly polluted waste waters from the chemical plant "Czarna Huta" in Tarnowskie Góry, of wastes from mechanical works of non-ferrous metals in Skrzybnica, and from the paper-mill in Borszowice. Below the mouth of the Stoła stream the River Mała Panew no longer receives any great loads of industrial wastes. Only a small amount of this kind of pollution passes to the River Mała Panew in its middle course from the ironworks in the locality Zawadzkie and in its lower sector, some kilometres above the recession of the dam reservoir at Turów (108 million cu. m. of water) situated on it, from the ironworks in Ozimek. Below the village of Zawadzkie a certain load of municipal sewage (from the town of Lubliniec) is fed with the waters of the Lublinianka stream. However, the content of microelements in the water of this stream is not high (Pasternak, Antoniewicz 1969).



Ryc. 1. Plan sieci rzecznej i rozmieszczenia zbiorników w otoczeniu huty cynku i ołowiu „Miasteczko Śląskie” z zaznaczeniem punktów poboru prób (1—11)

Fig. 1. The plan of the river system and the distribution of reservoirs in the vicinity of the zinc and lead works „Miasteczko Śląskie”, the sampling stations being marked (1—11)

The territory of the upper and, in the main, of the middle part of the catchment area of the River Mała Panew is composed of Triassic variegated clays and limestones, usually covered with a thick layer of glacial sands. A belt of dolomite orebearing rocks which occurs in the deeper substratum on the southern outskirts of the upper part of the catchment basin probably has no significant effect on the chemical composition of the water in the River Mała Panew. In the remaining sector of the middle part of the catchment basin of the Mała Panew (from the locality Zawadzkie) and in almost the whole lower part various kinds of Triassic clays (gray and variegated) are found under glacial sands, though usually not in complexes with limestones and dolomites but with slate clays and sandstones.

In the substratum of the upper catchment basin of the upper Brynica with the reservoir at Kozłowa Góra and the small mid-forest water body Chechło, rocks of age and quality similar to those in the upper part of the catchment basin of the River Mała Panew occur. The catchment basin of the River Brynica differs from that of the Mała Panew only in that among its Triassic rocks the calcareous and dolomite ones constitute a larger percentage. Moreover, on a sector of 2 kilometres the River Brynica flows through a territory whose deeper rocky layers are ore-bearing dolomites.

On the sandy rocks of the surface layer of the catchment basin of both investigated rivers podsolich soils were formed with the granulometric composition of loose sands, weakly loamy, or light loamy sands. Thus the soil cover of these territories is fairly permeable.

In their upper sectors the discussed rivers are deeply cut in the substratum. Between the mouth of the Stoła stream and the reservoir at Turów the River Mała Panew winds greatly and forms numerous shallow arms and flooded areas very often covered with flowering plants, this considerably increasing its ability of self-purification.

Method

In the waters and sediments of the reservoirs, rivers, and streams flowing in the region of the zinc plants, besides the content of microelements, basic chemical properties were also defined. They were determined with the use of generally applied methods. The microelements in the water were determined using an atomic absorption spectrophotometer (Standard Methods 1970) and in the bottom sediments using an emission spectrophotometer (Gliński, Grajpel 1965). In the river and streams the bottom sediments were sampled in several cross-sections on a sector of 50 m. The samples of water as well as of sediments were taken twice at the average water level in summer 1972 and twice at the higher water level in the winter-spring period 1973.

Tabela I. Ogólne właściwości chemiczne wody zbiorników, rzeki Małej Panwi i jej dopływów (wartości średnie)

Table I. General chemical properties of the water of reservoirs, the River Mała Panew, and its tributaries (mean values)

(Zbiornik) Rzeka; potok (Reservoir) River; stream	Miejscowość Zlewnia Locality Catchment basin	Nr punkt No of point	pH	Pien rozpuszczony mg O ₂ /l	Oxygen dissolved mg O ₂ /l	Ufialalność mg O ₂ /l	Twardość ogólna °g	Alkaliczność meq/l	mg/l				
									Ca	Mg	K	Na	Cl
(Kozłowa Góra) (Zalew Chechko)	Zlewnia rzeki Brynicy River Brynica catchment basin	1	8.2	11.52	8.6	9.4	1.80	50.7	9.9	2.80	6.40	16.5	67.4
		2	7.6	10.56	5.7	4.2	3.50	22.2	4.8	2.04	2.64	5.2	48.5
Mała Panew	Miotek	3	7.4	9.92	7.8	8.4	1.75	45.0	9.1	3.84	5.68	13.0	57.9
Mała Panew	Pusta Kuźnica	4	-	0.80	251.5	-	-	-	-	6.24	120.00	-	91.2
Stoża	Tworóg	5	7.4	5.44	14.1	19.3	3.10	107.2	18.6	9.24	96.00	151.0	188.3
Graniczna Woda	Tworóg	6	7.0	9.12	6.2	15.4	1.10	73.6	22.1	12.80	18.40	49.7	197.5
Stoża	Potępa	7	7.3	10.40	10.4	13.1	2.20	70.8	13.9	9.04	72.48	123.0	115.2
Mała Panew	Krupski Młyn	8	7.3	8.80	36.8	11.6	2.25	71.5	6.9	7.96	67.36	96.0	111.1
Mała Panew	Ozimek	9	7.3	8.48	23.0	8.1	1.75	42.9	9.1	4.92	31.68	39.0	75.4
(Turawa)	Turawa	10	7.3	8.85	14.9	7.6	1.60	37.9	10.0	4.30	24.20	27.5	71.7
Mała Panew	Węzry	11	7.4	9.00	12.5	7.2	1.50	35.7	9.5	4.00	21.80	23.5	68.8

Results of investigations of the water

As the determinations of the general chemical properties of the water from the region of the zinc plant suggest (Table I), clean water from the initial sector of the River Mała Panew (up to Kalety) is characterized by normal colour and oxidability, good oxygen saturation, weakly alkaline reaction, average content of calcium, magnesium, potassium, sodium, and chlorides, and slightly higher content of sulphates. Beginning from the locality Kalety the water of the Mała Panew has the colour of black coffee and its oxidability reaches enormous values. The oxygen content is nearly zero. Besides further increase in the content of sulphates a very high increase in sodium content occurs there.

Already before the inflow of the polluted water from the zinc plant "Miasteczko Śląskie" through the canal Graniczna Woda, the Stoła stream has water of a high degree of pollution. In general, the water of the Stoła is characterized by a great amount of sulphates and chlorides, sodium and potassium, and by considerably increased oxidability and total hardness as compared with the clean waters of this territory (Table I). It also contains a great amount of suspension with a considerable quantity of mineral suspension in it (among others particles of kaolin). According to the investigations of Wysokińska et al. (1963), about 134 mg of suspension occurs on the average in 1 l of water from the Stoła below the papermill in Boruszowice. In consequence, the water of this stream has great turbidity and a specific ashy-grey colour.

The direct receiver of partly treated wastes of the zinc plant, the canal Graniczna Woda, has almost clear (only slightly opalescent) water, well oxygenated, of average oxidability, and, owing to the neutralization treatment carried out in the zinc plant, of neutral reaction (Table I). In the chemical composition of the water of this stream considerable total hardness, and in it a high content of magnesium and potassium, and a very high one of sulphates, is striking. It should also be mentioned that the stones of the bottom of this stream are covered with tufts of filamentous green algae.

Below the mouth of the Stoła stream the water of the River Mała Panew once more changes its basic chemical character, a decrease in the content of organic matter (oxidability) being accompanied by an increase in the content of calcium, sodium, potassium, sulphates, and chlorides.

On further sectors of the middle river course the water of the Mała Panew already undergoes successive self-purification. This is visible in a further increase in its oxidability and in the content of calcium, sodium, and of chlorides. It should also be stressed that the decrease in the Ca content in the water is a factor favouring the dissolution of lead. According to Collienne and de Graeve (1973), soft waters are more aggressive in relation to this element. In this sector of the Mała Panew, as well as in its whole course, the content of iron in the water is fairly high and relatively invariable

Tabela II. Średnie zawartości metali ciężkich w wodzie zbiorników, rzeki Mażej Panwi i jej dopływów
(z całego okresu badań)

Table II. Mean content of heavy metals in the water of the reservoirs, the River Maża Panew, and its tributaries (from the whole investigation period)

(Zbiornik) Rzeka; potok (Reservoir) River; stream	Miejscowość Zlewnia Locality Catchment basin	Nr punktu No of point	µg/l									
			Cu	Zn	Pb	Ca	Cr	Mn	Co	Ni	Fe	
(Kozłowa Góra)	Zlewnia rzeki Brynicy	1	6.25	23.3	5.0	1.56	8.0	44.8	9.30	7.4	175	
(Zaław Czechko)	River Brynica catchment basin	2	8.70	67.3	2.4	0.94	3.5	32.3	6.25	2.5	150	
Maża Panew	Młotek	3	7.50	41.0	2.5	1.88	4.1	100.0	9.38	7.5	1040	
Maża Panew	Pusta Kuźnica	4	8.80	89.3	17.5	2.19	8.3	175.0	12.50	12.5	1125	
Stoża	Tworóg	5	27.50	5000.0	13.7	422.00	16.5	335.8	12.50	30.0	908	
Graniczna Woda	Tworóg	6	6.25	43100.0	175.0	1325.00	4.5	420.0	9.38	10.0	721	
Stoża	Potępa	7	18.75	10375.0	30.0	450.50	8.3	435.3	9.40	25.0	1448	
Maża Panew	Krupski Młyn	8	12.50	7700.0	15.0	130.00	25.0	370.0	15.62	15.0	1198	
Maża Panew	Ozimek	9	62.80	958.0	22.5	13.50	16.5	315.0	12.50	13.8	3185	
(Turawa)	Turawa	10	36.40	280.7	25.5	7.20	11.0	277.0	9.85	11.7	1450	
Maża Panew	Węgrzy	11	29.80	218.5	17.0	5.30	9.2	268.0	8.78	10.0	1012	

(Table II). In the lower course of the Mała Panew a particularly positive role in the self-purification of the water is played by the reservoir at Turawa, below its dam the general state of purity of the water in the river being much improved (Table I — Hungary).

Similarly as the upper sector of the River Mała Panew, the reservoirs at Kozłowa Góra and at Chechło have relatively clean water. As compared with the clean water of the spring sector of the Mała Panew, the water of the reservoir at Kozłowa Góra has only slightly more calcium and magnesium, a more alkaline reaction, and considerably less iron.

The water of the shallow reservoir Chechło, which was formed, for recreation purposes, by flooding an excavation after the exploitation of sand, is characterized by high oxygenation, very small content of calcium and magnesium, and small iron content. Such chemical properties of the water of this reservoir in a great measure result from the mass development of submerged plants (biological decalcification of water and precipitation of iron).

The content of microelements in the waters of streams and rivers which are direct or indirect receivers of wastes from the zinc and lead works at Miasteczko Śląskie and in the water of the reservoirs situated in the region of these works is presented in Table II. As these data indicate, the concentration of almost all investigated microelements in the water of the upper sector of the River Mała Panew and of the reservoirs at Kozłowa Góra and Chechło, which lie within the zone of the weakened fallout of dusts from the works, does not show any significant deviation from the average values found in this type of clean waters (Pasternak 1971, Robbins et al. 1973, Ebner et al. 1973). In the water of the Mała Panew a distinct increase occurs in the amount of microelements down to below the inflow of organic wastes from the cellulose plant at Kalety. This increase above all concerns the amounts of lead, zinc, chromium, nickel, and cobalt. Nevertheless, high concentrations of numerous microelements are noted only in those sectors of the river network of the Mała Panew where the inflow of wastes from the zinc plant and other industrial works occurs. The highest concentrations of some microelements occur in the direct receiver of wastes, i. e. in the Graniczna Woda stream and in the successive Stoła stream.

Already before it mixes with the wastes from the zinc plant the water of the Stoła contains several times more zinc, cadmium, copper, nickel, and lead than any average polluted surface water (Kopp, Kroner undated, Pasternak 1973, 1973a, Pasternak et al. 1974). The high concentration of copper and nickel in the water of this sector of the Stoła stream suggests that the main source of the contamination with heavy metals of its middle sector is the inflow of mineral wastes from chemical works in Tarnowskie Góry and from mechanical ones at Strzybnica.

In the Graniczna Woda stream the content of zinc, cadmium, and lead in the water is still higher, the level of the concentration of these elements

considerably exceeding the amounts permitted by Polish norms for wastes fed into rivers. In the quantitative composition of microelements of the water of this stream an exceptionally high content of cadmium and a wide proportion of zinc and lead are striking. This relation is much narrower, amounting to about 2:1 in the dusts emitted by the metallurgical works "Miasteczko Śląskie" (Paluch, Karweta 1970). An important fact resulting from the investigations of the above-mentioned authors worth noting here is that in the green parts of the plants it is still narrower (1:1). This fact supports the findings of Bowen (1966) and Cowgill (1970) that the aquatic plants have a great selective capacity of accumulating lead in spite of the fact that this element is not indispensable for them. The occurrence of green epiphyte algae in the Graniczna Woda stream and also in the canal No 3 draining water from the zinc mining works (Pasternak 1973) indicates that in the waters rich in calcium and magnesium certain plants can withstand great concentrations of lead, zinc, and cadmium. The presence of certain algae and bacteria in the sediments settling down on the river bottom (a tributary of the Missouri) and coming from the zinc wastes of zinc mining works was also observed by Jennet and Wilson (1972). However, it does not exclude the fact that the amounts of Zn and Pb found in this stream are already in the range of concentrations regarded as distinctly noxious for many aquatic organisms, especially for small animals (Karbe 1972, Malanchuk, Gruending 1973). The content of copper, chromium, and cobalt in the water of the Graniczna Woda stream is on an average level.

In the Stoła stream some kilometres below the inflow of wastes from the metallurgical works, the content of Zn and Pb in the water almost doubles under the influence of these wastes. The content of cadmium increases in a lesser degree. In comparing the determined values of Zn and Pb increase in the water of this sector of the Stoła with the theoretical value resulting from the multiplicity of the dilution of wastes from the zinc works by the water of the Stoła (an approximately sixfold dilution, a part of this water being that of two small, completely clean, streams) and with the amount of metals in the water of this stream above the inflow of the wastes, one may observe that owing to the self-purification of the stream on the discussed sector the difference between these two values is very small. This suggests that the actual biological ability of self-purification from heavy metals of the lower sector of the Stoła is insignificant. The process of self-purification of the Stoła from such metals is undoubtedly inhibited in some measure by the inhibiting action of the too high concentrations of several metals on various organisms taking part in it and by the content of very small suspensions which sedimentate poorly from the water and prevent the penetration of light to it. Nevertheless, it is difficult to find out precisely in what measure the determined level of metals in the water of the Stoła can act toxically, since this depends on very many co-acting factors. Malanchuk and Gruending (1973) come to a similar conclusion on the basis of investigations on the

toxicity of lead nitrate on 5 species of algae from weakly mineralized clean waters. It must be stressed that for the last few years no fish have appeared in the Stoła and the development of various algae is very poor.

In the locality Potępa the inflow of the water from the Stoła, strongly polluted with heavy metals, to the River Mała Panew (in the ratio 1:2) results in a rapid increase in the quantitative level of almost all investigated elements. Above all the content of zinc and cadmium very markedly increases in this sector of the Mała Panew (Table II). The concentration of these elements is higher than that permitted by the norms, while the content of lead is maintained at the level recorded in the water of this river above the mouth of the Stoła stream.

On the first kilometres of this part of the Mała Panew the average content of cadmium in the water is still so high that it exceeds the maximum concentration of this element ($120 \mu\text{g Cd/l}$) found by Knopp and Kroner (undated) in the polluted waters of the USA (the river Cuyahoga, a tributary of Lake Erie, an industrial region).

In connection with a very slight amount of cadmium in the lithosphere and poor solubility of its carbonates and hydroxides in the water, the concentration of this element in the relatively clean surface waters, as the data in Table II and the results of Knopp and Kroner (undated) indicate, usually ranges from a fraction of $\mu\text{g/l}$ to $5 \mu\text{g/l}$. Besides the zinc industry, the source of cadmium in the polluted waters and in the air may also be, among others, certain plastics and pesticides containing this element.

In the course of the River Mała Panew the content of cadmium, zinc, chromium, manganese, cobalt, and nickel successively decreases. Among the metals mentioned above the cadmium content decreases most rapidly in the water. Before the locality Ozimek, lying 44 kilometres below the mouth of the Stoła, the content of this element is already only about 10-times higher than the average. On this sector the fairly intense self-purification of the waters of the River Mała Panew is probably in a great measure favoured by the above-mentioned specific character of its bed (shallow flooded areas considerably overgrown by flowering plants). As compared with the first kilometres of this river sector in its lower course at Ozimek a great increase in the content of copper and iron and a slight one in that of lead are noted. It seems that this results from a certain inflow of metallurgical wastes in the locality Zawadzkie.

Further self-purification of the water of the Mała Panew from heavy metals (also from those which pass with the polluted waters of the metallurgical works at Ozimek) occurs in the dam reservoir "Turawa". A particularly great decrease in the content of zinc and cadmium from the water of this reservoir is recorded. The content of copper is still maintained at a high level. It is probable that a fresh inflow of this element from the metallurgical works at Ozimek contributes to it in some measure. Such a high degree of self-purification from zinc of the water of the reservoir at Turawa is probably

connected not only with the biological consumption of this element by plankton algae which develop more intensely in the reservoir than in the river, but also with the physico-chemical precipitation resulting from the mineralization of a great part of dissolved organic substances in the water (cellulose wastes) with which in the upper river course zinc has formed soluble complex compounds, making possible its longer maintenance in water even with more alkaline reaction. In reservoirs the activation of the self-purification processes of the water from heavy metals is also in some measure influenced by a considerable dilution of the pollution carried by the river in the waters of the reservoirs and by the longer period in which the partly treated water masses remain within the reservoir. The negative balance of heavy metals in the water of the dam reservoir was already found by the author in his earlier works (Pasternak 1971).

In the mouth sector of the Mała Panew (below the dam at Turawa) a further decrease in the content of all investigated microelements is recorded. However, this reduction is not great enough to bring the amount of these elements in the water of this river sector to the level noted in clean rivers (Knopp, Kroner undated, Abdullah, Royle 1972, Pasternak 1973) or even in the relatively clean spring sector. In this sector of the river above all the content of zinc, copper, cadmium, lead, and manganese is still considerably higher than the average for clean rivers.

Results of the investigations of sediments

The total content of microelements in the bottom sediments of rivers, streams, and reservoirs in the region of the metallurgical works "Miasteczko-Śląskie" is presented in Table III against the background of the basic physico-chemical properties of these sediments. As these data indicate, the sediments lining the bottom surface of all the investigated water bodies have the granulometric composition of sands, and also in the bottom of reservoirs of strong loamy sands and in that of the River Mała Panew and its investigated tributaries usually of loose sands (Table III). Only the sediments of the streams whose water carries a larger amount of mineral suspension contain more silty particles (< 0.02 mm). Among others the sediments of the Stoła stream are in the group of such sediments.

The sediments of the Kozłowa Góra have a weakly acid reaction (Table III), the sediments in the river system of the Mała Panew showing distinct spatial variability. Namely, in the upper sector of this river and its tributaries (up to the locality Krupski Młyn) the sediments have a weakly alkaline reaction while in the middle and lower ones, where the total hardness of water successively decreases (Table I), the reaction is more or less acid. In the lower part of the Mała Panew the greatest acidification was found for the sediments of the reservoir at Turawa.

Tablica III. Zawartość mikroelementów, ilastych frakcji, materii organicznej i pH w osadach dennych rzeki Mażej Panwi i jej dopływów oraz zbiorników w okolicy huty cynku i ołowiu

a - średnie z okresu letniego 1972; b - średnie z okresu zimowo-wiosennego 1973

Table III. Content of microelements, clay fractions, organic matter, and pH in bottom sediments of the River Maża Panew, its tributaries and reservoirs in the region of zinc and lead foundries

a - mean values from the summer period 1972; b - mean values from the winter-spring period 1973

(Zbiornik) Rzeka; potok (Reservoir) River; stream	Miejscowość Zlewnia Locality Catchment basin	Nr punktu No of point	War- tości Va- lues	ppm													Frakcja ilasta Clay fraction <0.02 mm	Materia organiczna Organic matter %	pH
				Cu	Zn	Pb	Cd	Mn	Ni	Co	Cr	Mo	V	Sr	Ba	B			
(Kozłowa Góra)	Zlewnia rzeki Brynicy	1	a	19.9	367	195	-	291	10.5	2.9	21.0	14.6	16.0	38	416	55	3	2.80	6.15
			b	22.8	405	234	14.6	366	20.1	10.0	33.7	20.0	29.2	46	705	64			
(Zalew Cheoń)	River Brynica catchment basin	2	a	23.7	265	179	-	541	16.8	1.8	30.0	4.6	28.9	120	1500	59	7	1.81	6.50
			b	25.0	270	188	90.0	520	19.0	8.2	28.0	5.4	30.0	112	2400	68			
Maża Panew	Miotek	3	a	14.6	287	60	-	502	9.1	1.2	8.9	3.6	6.0	29	290	52	2	0.81	7.50
			b	13.0	260	54	13.0	480	8.8	2.8	8.4	3.3	6.0	9	124	50			
Maża Panew	Pusta Kuźnica	4	a	11.3	100	47	-	176	7.5	3.1	9.7	3.2	11.0	16	180	47	1	0.56	7.30
			b	8.8	136	59	3.4	164	6.0	1.8	10.3	4.0	9.4	15	131	40			
Stoża	Tworóg	5	a	200.0	5000	150	-	402	10.0	3.8	33.2	4.0	10.0	620	1500	63	2	4.03	6.95
			b	134.0	3800	230	116.0	460	13.0	3.4	31.0	4.4	6.8	152	2500	74			
Graniczna Woda	Tworóg	6	a	19.4	3000	200	-	192	12.0	1.8	10.0	7.0	5.0	36	250	46	3	0.91	7.15
			b	18.0	1800	220	15.2	200	10.0	1.4	11.6	5.0	9.0	10	170	50			
Stoża	Potępa	7	a	66.5	2650	135	-	341	7.0	1.0	7.7	3.8	6.1	40	1078	54	4	1.41	7.30
			b	42.0	1640	148	31.0	360	8.8	1.4	8.6	4.0	5.4	31	1120	50			
Maża Panew	Krupski Młyn	8	a	19.1	329	82	-	189	7.9	2.5	6.7	3.5	6.1	38	575	43	3	0.50	7.10
			b	18.4	350	68	4.0	180	3.6	1.6	5.2	3.1	3.6	27	640	40			
Maża Panew	Ozimek	9	a	20.4	302	27	-	100	6.2	1.7	4.5	3.9	5.1	12	101	45	1	0.66	6.60
			b	12.0	320	24	2.0	70	5.4	1.2	3.6	3.4	4.4	7	96	40			
(Turawa)	Turawa	10	a	226.0	562	315	-	479	39.3	14.4	33.5	19.6	21.3	156	796	58	8	9.62	5.10
			b	185.0	798	490	9.8	875	42.9	23.8	41.0	35.7	40.0	147	925	64			
Maża Panew	Węgrzy	11	b	43.2	148	41	1.0	151	11.6	6.1	14.2	5.7	9.7	34	160	40	2	0.52	6.40

The content of organic matter in the sediments of separate investigated aquatic environments is fairly differentiated (Table III). Usually a higher content is found in the sediments of reservoirs than in those of streams and rivers. In the region of Kalety, in spite of great organic pollution of the water, the River Mała Panew has sediments of low and little differentiated content of organic matter in the whole length of its riverbed (the sediments of the reservoir at Turawa not being taken into consideration). It seems that this is chiefly connected with the specific character of the organic pollution from the factory at Kalety. For the most part this pollution occurs in the water in the form of dissolved compounds or very finely ground light cellulose fibres which are therefore easily carried over a long distance by the water (even with a slow rate of flow) and in only very small amounts settled on the bottom of the river near the source of pollution. The pollution accumulated on sandy bank shoals with slow water current are more rapidly mineralized than on silty bottoms of rivers. A great percentage of the pollution organic matter which has not been mineralized in the water of the Mała Panew, does not accumulate until it reaches the bottom of the Turawa reservoir, in an environment with physico-chemical properties different from those of the river and in almost stagnant water. This results from the very great amount of organic matter found in the bottom sediments of this reservoir. In the case of the Stoła stream, whose water receives in a great part organic pollution of another kind (municipal sewage), the amount of organic matter in the bottom sediments is fairly great and shows a correlation with the total content and spatial differentiation (a decrease down the stream) of organic substances in the water.

As the data in Table III indicate, the concentration of the majority of the investigated microelements in the sediments of the reservoirs at Kozłowa Góra and Chechło and of the initial sector of the bottom of the River Mała Panew, which are within the range of the weakened fallout of dusts emitted by the "Miasteczko Śląskie" metallurgical works, is decidedly increased since it considerably exceeds the average content of these constituents not only in sandy but even in silty sediments of clean lakes, reservoirs, and rivers (Shimp et al. 1971, Brooks, Quin 1971, Gregor 1972, Pasternak, Gliński 1972, Pasternak 1974). A greater increase in the content of microelements in relation to the average occurs in the sediments of reservoirs than in those of the initial sector of the River Mała Panew. Contrary to the picture of the occurrence of microelements in the waters of the reservoirs presented above, these phenomena indicate that the emission of dusts by the zinc and lead works decidedly influences the properties of neighbouring aquatic environments. The absence of any distinct reflection of the influence of the emission of dusts by the metallurgical works in the quantitative level of microelements in the water most probably results from 2 coincident processes. The first one of them is the rapid sedimentation of mineral particles of dust settled on the water surface or washed from the catchment basin to the bottom

of the water body, and consequently a certain decrease in the solubilization of metal compounds contained in them. The other process is the secondary biological and physico-chemical precipitation of a part of the dissolved metal compounds from the alkaline and well-oxygenated water. In the sediments under the waters of this part of the vicinity of the metallurgical plant at "Miasteczko Śląskie" (the zone of weak fallout of dusts) a high sub-concentration of Zn, Pb, Cd, Ni, Mn, Ba, and Sr is above all noted. The exceptionally great inflow of zinc and nickel to the water from the air contaminated by towns and industry was found by Winchester and Nifong (1973) on the example of Lake Michigan. In the sediments of the Czechło reservoir barium and strontium occur in particularly great amounts. This suggests that the reservoir and its direct catchment basin remains not only under the influence of the emission of dusts from the zinc plant but also, or perhaps above all, of the emission of dusts from the chemical works "Czarna Huta" which are situated on the west side, much nearer to this reservoir than the zinc works (fig. 1).

The next sector of the River Mała Panew polluted with organic wastes, being situated on the north-east side of the zinc works and therefore rarely remaining under the influence of dusts emitted by them, has sediments with a lower content of Zn, Pb, Cd, Ba, and Sr than the initial sector of the river discussed above. However, it should be stressed that this phenomenon may to a certain degree result from conditions adverse to the precipitation of heavy metals from the water of this river sector. In this water such conditions originate from the presence of a very great amount of organic substances with which the metals readily form soluble complex compounds.

In the microchemical composition of the sediments of the Graniczna Woda stream, which receives a direct inflow of wastes from the zinc works, only a very high content of zinc, lead, and cadmium is noted. The other investigated microelements occur in almost average amounts in the waters of this stream. However, it should be stressed that the content of Zn, Pb, and Cd, which is high in the sediments of the Graniczna Woda, is not so great as might be expected on the basis of the enormous content of these elements in the water. The amount of zinc in the sandy sediment of this stream does not even reach such a range of concentration of this element as was recorded in the finely granular mud of the settling tanks of municipal and industrial sewage in several localities of West Germany (3000—7000 ppm) mentioned in one of Hellmann's papers (1972). This suggests that the self-purification of the water from these metals is relatively weak within the reservoir.

In the sediments of the whole investigated sector of the Stoła stream the concentration of determined microelements attains very high values (Table III). In the sediments of this stream besides Zn, Pb, and Cd, very great amounts of Cu, Ba, and Sr and great amounts of Cr and B occur. On the basis of the data given in the works of Lauenberger and Hartmann (1971)

and Mathis and Cummings (1973) one may draw the conclusion that the amount of zinc and cadmium in the sediments of this stream, with the coincident great content of copper, which synergistically affects the toxicity of zinc, may already be classified among the concentrations negatively influencing certain more susceptible species of the bottom fauna and bacteria. A high concentration of Ba, Sr, Cu, and B in the sediments of the Stoła suggests that this stream is not only polluted with heavy metals from the zinc works but also from other industrial establishments. With regard to the fact that among others the Stoła is also the receiver of sewage from the works "Czarna Huta", the high content of barium and strontium in its sediments supports the above-mentioned hypothetical conclusion that the emission of dusts from these works is the main source of contamination of the reservoir at Chechło.

In comparing the concentration of microelements in the sediments of the Stoła in the zone lying above the point where the wastes from the metallurgical plant "Miasteczko Śląskie" are released and in the mouth zone it may be said that with the flow of the stream a decrease in all determined elements occurs. Thus the inflow of the wastes of the Graniczna Woda stream, rich in Zn, Pb, and Cd, brings about no increase in the accumulation of these 3 constituents in the sediments of the mouth sector of the Stoła. Even the occurrence of great amounts of suspension capable of absorbing on its surface heavy metals dissolved in the water and of sedimentating with them on the bottom (Lobčenko, Kaplin 1968) does not contribute to it, since the sedimentation of clayey suspensions on the bottom of this stream is disturbed by the too rapid current of the water. The lack of more intense accumulation of Zn and Pb in the sediments in the mouth sector of the Stoła indicates that the purification of the water from these elements is very slight in this sector of the stream. In the sediments of the Stoła sampled above the inflow of wastes from the zinc plant the content of copper is exceptionally high, equalling its average content in the sediments of the most polluted sector of the Czarna Przemysza, which collects the wastes from the industrial region of Silesia (Pasternak et al. 1974). Hence it may be said that in the water of the upper sector of the stream the degree of the pollution with copper as well as the intensity of its precipitation from the water are very high. With the flow of the stream the precipitation of copper from the water so much decreases that in the sediments of the mouth sector of the Stoła its amount is already about three times lower. It seems that this phenomenon is connected not only with an admixture of polluted waters, poor in copper content, from the zinc works (Table II) but also with the fairly intense precipitation of copper from the water of the Stoła, rich in calcium and magnesium (Table I).

In the sediments of the River Mała Panew below the inflow of the polluted waters of the Stoła a distinct increase in the content of Zn, Pb, Ba, Cu, Sr and Cd occurs.

western winds. Generally speaking, this influence is not yet great and is considerably less than could be expected on the basis of the total emission of dusts by the plant and of the zinc and lead content in them. In 1971 the annual dust emission of the discussed plant was evaluated at 1500 tons of which 300 tons was Zn (20 per cent) and 200 tons Pb (14 per cent). This still relatively small effect of dust emission of the plant "Miasteczko Śląskie" on the neighbouring surface waters is causally related to many factors active in the vicinity of the works. It seems that above all it results from the space differentiation in the fallout of heavy dusts containing zinc and lead (i.e. strong near the works and weak in further areas), from the flat relief of the country surrounding the works, and from great areas covered with forests and meadows, this inhibiting the surface washing of dusts by rain water to streams and rivers. As the investigations of Paluch and Karweta (1970) indicate, the greatest amounts of dusts containing zinc and lead are retained in afforested areas. Besides the plant cover, the factor buffering the effect of dusts or heavy metals dissolved by rain water on the environment of surface waters, is the soil cover. It was found in the collective investigations conducted in the USA (collective work 1968) and in the experiments of Lehman, Wilson (1971) and Wentink, Etzel (1972) that if the land soils are not yet in a greater degree enriched with heavy metals, they are capable of sorptive capture and of purification of waste waters from heavy metals. Hence by way of analogy one may suppose that in the first year of the activity of a plant such a role is played by the soils in its vicinity. It also seems that a very important factor preventing the washing of heavy metals out of the contaminated soils in the vicinity of metallurgical works is the simultaneous penetration of great amounts of basic compounds, which diminish the solubilization of metals, from the dusts in the air into the soils, since it is known that an increase in the soil pH (by liming) fixes a considerable part of trace elements, preventing their migration to water (Cottenie 1972). If in the further years of activity of the works the emission of SO₂ and sulphuric acid, and in consequence the acidity of soils in their neighbourhood, increased, the situation might radically change. In connection with the accumulation of zinc and lead in the most superficial soil layer (Skawina 1967, Paluch, Karweta 1970, Turski, Baran 1972) and with the complicated circulation of underground waters discussed in the introduction, any great penetration of metals to the surface waters through the ground waters, is hardly possible in spite of the great permeability of soils in the environs of the works. Nevertheless, with any other course of the contamination processes on the areas covered with permeable sands, the sub-concentration of lead may occur in the ground waters (Mainz et al. 1973). Recently in West Germany the contamination of soils and of underground waters with lead from admixtures of petrol was noted in the regions of busy lines of communication (Golwer, Schneider 1973).

In the discussed region, besides the zinc plant, a serious source of microelements penetrating to the surface waters are the "Czarna Huta" works.

In the sediments of this part of the river the content of other microelements is variable but in the main similar to the concentration of these elements recorded in the sector above the mouth of the Stola.

In the further course of the Mała Panew, down to the locality Ozimek, the content of microelements, with the exception of copper, molybdenum, and barium, decreases in the sediments. In this river sector the content of individual elements decreases in the sediments in various degrees, the greatest reduction being observed in the content of strontium, barium, lead, and manganese, and the smallest in the content of zinc. The almost unchangeable level of the copper content, and even its slight increase in the summer period, probably results from the inflow of a certain amount of mineral pollution to the Mała Panew in the region of the locality Zawadzkie. It seems that the reduction in the strontium content to an almost normal level in the sediments of this river is connected with the selective water purification by the flowering plants overgrowing the riverbed, since many plants of that type assimilate strontium more strongly than calcium (Gaudet 1973).

In the sediments of the water reservoir at Turawa the accumulation of all microelements is much greater than in the river. Particularly great amounts of copper, lead, manganese, barium, zinc, and cadmium accumulate in the sediments of this river. This phenomenon supports the observation, mentioned in discussing water properties, that the reservoir at Turawa is a factor facilitating the self-purification of the River Mała Panew from heavy metals and other unfavourable components. It is worth noting with regard to the cadmium content in the sediments of the reservoir at Turawa that in the sediments under clean waters its concentration does not very often exceed even 1 ppm (Bowen 1966, Mathis, Cummings 1973).

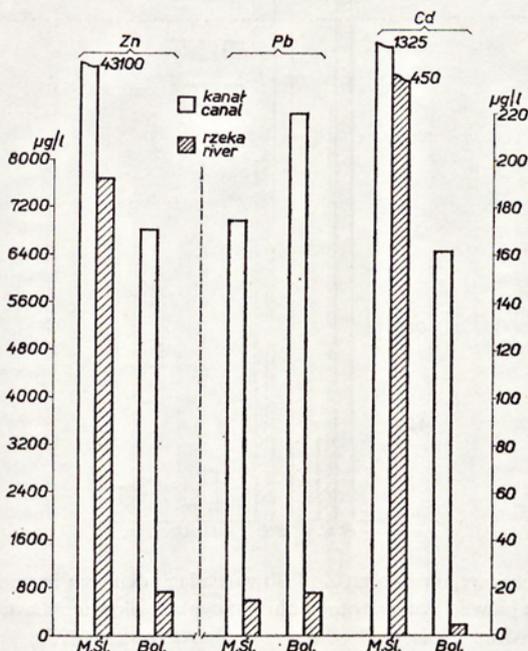
In spite of this intensified self-purification of the water in the Turawa reservoir, below the dam the sediments of the River Mała Panew contain still higher amounts of zinc, copper, and lead than the sandy sediments of the clean stream (Pasternak 1973). This fact additionally supports the opinion that up to the end of the river course no complete purification from the surplus of heavy metals which penetrate to the Mała Panew with industrial wastes occurs in this river.

Recapitulation and conclusions

The obtained results suggest that the state of purity of the surface waters in the neighbourhood of zinc and lead mining and smelting industries is affected not only by fluid wastes but also by the pollution of the air already in the initial period of industrial activity. The influence of dusts emitted by the zinc and lead plant at Miasteczko Śląskie is noted only in those aquatic environments which lie on its eastern side, i.e. in the line of the prevailing

The dust fallout from these works effects a very high increase in the content of barium and cadmium in the environment of neighbouring waters.

The pollution of the zinc plant, released in the form of wastes to streams and then to the River Mała Panew, increases the content of Zn, Pb, and Cd in their waters to a very high level. In the first receiver of these wastes — the Czarna Woda stream — the average content of zinc and cadmium in the water is over four times higher than in the water of a similar canal draining the waste waters, neutralized from the sulphuric acid, from a plant of another centre of the zinc industry (Boleslaw, fig. 2).



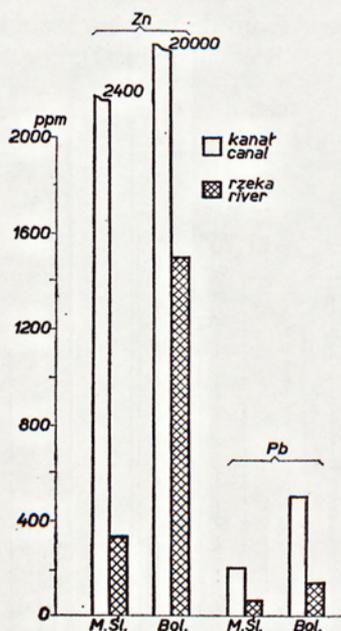
Ryc. 2. Porównanie poziomu stężenia Zn, Pb i Cd w wodzie bezpośrednich odbiorników ścieków (kanałów) oraz głównej rzeki w otoczeniu hut cynku i ołowiu „Miasteczko Śląskie” (M. Śl.) oraz „Bolesław” (Bol. — wg Pasternaka 1973 a).

Fig. 2. Comparison of the level of Zn, Pb, and Cd content in the water of direct waste receivers (canals) and of the main river in the vicinity of the zinc and lead works „Miasteczko Śląskie” and „Bolesław” („Bol.” — according to Pasternak 1973a)

In the case of sediments quite reverse proportions of Zn and Pb content occur between these two centres.

The content of Zn and Pb in the sediments of the Czarna Woda stream (canal) is six times lower than in the sediments of the canal draining waste waters from the “Bolesław” metallurgical works (fig. 3). It indicates that a too high concentration of Zn, Pb and Cd in the direct receivers of zinc and lead smelting works inhibits the self-purification processes of the water.

The data in figs 2 and 3 also distinctly indicate a difference in the range of influence of metallurgical waste waters on the level of Zn, Pb, and Cd concentration in the water of the main rivers draining the regions where the two compared industrial centres are situated. The degree of the negative effect of the waste waters on the main river is decidedly lower in the case of the "Bolesław" works.



Ryc. 3. Porównanie ilościowego poziomu Zn i Pb w osadach dennych bezpośrednich odbiorników ścieków (kanałów) oraz głównej rzeki w otoczeniu hut cynku i ołowiu „Miasteczko Śląskie” (M. Śl.) oraz „Bolesław” (Bol. — wg Pasternaka 1973b)

Fig. 3. Comparison of the quantitative level of Zn and Pb in the bottom sediments of the direct waste receivers (canals) and of the main river in the vicinity of the zinc and lead works „Miasteczko Śląskie” (M. Śl.) and „Bolesław” („Bol.” — according to Pasternak 1973b)

The contamination of the environment of head waters with heavy metals contained in the wastes is not of a local character as is the case with the land environment. Heavy metals which penetrate to waters flowing along various routes migrate over considerable distances, decreasing, with greater concentrations, the level of water purity. The length of the migration sector depends not only on the load of metals released to the river but also on the chemical properties of the water and hydrological regime of the given river. In the case of the investigated system of head waters the degree of the distribution of heavy metals from various pollution is very high. Among others, the high content of dissolved organic compounds in the water of this

river contributes to the lengthening of the sector of migration of heavy metals in the River Mała Panew.

In consequence of the prevalence of soluble organic compounds in the water and of the high rate of its flow (it flows down an upland) the content of organic matter in the sediments of the River Mała Panew does not show a positive correlation with the amount of organic matter fed with the wastes or with the space distribution of the sources of these wastes.

Besides the great content of organic substances, the exceptionally high cadmium content, rarely found in any other strongly polluted water, above all decreases the class of purity and the utility value of the water of the Stoła stream and the River Mała Panew on the sector from the mouth of the Stoła to the Turawa reservoir (50 kilometres). In the last years this element, if appearing in higher concentration in the environment, is classified beside mercury and lead in the group of poisons most dangerous for life, bringing about irreversible changes, especially in mammals (Tucker 1972, Mathis, Cummings 1973), since, similarly as lead, it cumulates in living tissue and has longlasting toxic effects. In connection with its ability of cumulating in the walls of the blood vessels, in the kidney and liver of mammals, it is regarded as the main factor of the increasing number of people suffering from high blood pressure. In 1972 a Working Group of the World Health Organization undertook research on the problem of the noxiousness of heavy metals for human health. The following limits of concentrations in drinking water were established for the metals: cadmium 0.005 mg Cd/l, lead 0.05 mg Pb/l, mercury 0.001 mg Hg/l, manganese 0.1—0.5 mg Mn/l (Collective work 1973).

A practical conclusion may be drawn from the above findings: that because of the very high concentration of cadmium (exceeding the above-mentioned limits) and of zinc, with the coincident high content of lead and copper, and also because of the successive decrease in its hardness and the presence of high amounts of iron and manganese, the water of this 50-kilometre long sector of the River Mała Panew cannot be used for drinking without the introduction of efficient measures removing heavy metals into the classic technology of its treatment.

The content of microelements in the tap waters of the dam reservoir at Kozłowa Góra is not as yet a factor decreasing its class of purity. Nevertheless, the effect of dusts emitted by the two industrial establishments discussed above on this reservoir may be already regarded as a strong factor eutrophivating its environment.

In the bottom sediments of the investigated water bodies more microelements are accumulated in the summer than in the winter period.

In the case of the coincidence of various sources of pollution in the environment of head waters a precise determination of the occurrence of heavy metals in them must be based on the simultaneous determination of these metals in the water and in the sediments.

STRESZCZENIE

W publikacji przedstawiono wyniki badań nad wpływem różnych zanieczyszczeń huty cynku i ołowiu w Miasteczku Śląskim na poziom stężenia, akumulację i rozprzestrzenianie metali ciężkich w środowisku wód powierzchniowych. Badania te obejmowały zbiorniki wodne i cieki usytuowane na obszarach otoczenia huty, które pozostają wyłącznie pod wpływem zanieczyszczenia powietrza oraz cieków lub ich odcinków otrzymujących zrzuty ścieków, z całą główną rzeką Małą Panwią włącznie i zbudowanym na niej zbiornikiem „Turawa” (ryc. 1). Mikroelementy w wodzie oznaczano za pomocą atomowego spektrofotometru absorpcyjnego, a w osadach dennych spektrofotometru emisyjnego. Zbadano także podstawowe właściwości fizykochemiczne wód (tabela I) i osadów (tabela III) oraz scharakteryzowano zlewnię.

Występowanie metali ciężkich w wodach i osadach rozpatrzono na tle ich podstawowych właściwości oraz ogólnej sytuacji zanieczyszczeniowej okolicy. Między innymi stwierdzono, że na stan czystości wód powierzchniowych w otoczeniu hut cynku i ołowiu już w pierwszym okresie działalności takich zakładów wpływa nie tylko zrzut ścieków, lecz także zanieczyszczenie powietrza. Wpływ pyłów emitowanych przez przedmiotową hutę zaznaczył się w ilościowym składzie mikroelementów tylko w tych środowiskach wodnych, które usytuowane są od wschodniej jej strony, tj. na kierunku najczęściej wiejących wiatrów zachodnich. Ogólnie biorąc jest on na razie niewielki i znacznie mniejszy, niż można by wnosić z całkowitej emisji pyłów przez hutę i zawartości w nich cynku i ołowiu. Fakt ten znajduje przyczynowy związek z wieloma czynnikami działającymi w otoczeniu hut, które w opracowaniu omówiono. Imisja pyłów odzwierciedla się głównie w ilościowym składzie mikroelementów w osadach (tabela III).

W badanym terenie oprócz huty cynku i ołowiu poważnym emitorem mikroelementów dostających się do wód powierzchniowych są zakłady „Czarna Huta”. Opad pyłów emitowanych przez te zakłady powoduje przede wszystkim duży wzrost w środowisku okolicznych wód (zbiornik Chechło) ilości baru i kadmu.

Zanieczyszczenia huty zrucane w postaci odpadowych wód do potoków, a w dalszej kolejności do rzeki Małej Panwi podnoszą w wodzie tych cieków zawartość Zn, Pb i Cd na bardzo wysoki poziom (tabela II). W pierwszym odbiorniku tych ścieków, zwanym Graniczną Wodą, średnia zawartość w wodzie cynku i kadmu jest ponad czterokrotnie wyższa niż w wodzie analogicznego kanału odprowadzającego zubożnione z kwasu siarkowego wody odpadowe z huty innego ośrodka przemysłu cynkowego (Bolesław — ryc. 2). Odwrotnie natomiast przedstawiają się proporcje zawartości Zn i Pb pomiędzy tymi dwoma ośrodkami w przypadku osadów (ryc. 3). Wynika z tego, że zbyt duże stężenia Zn, Pb i Cd w wodzie cieków hamują ich samooczyszczanie. Z rycin 2 i 3 widać także, że stopień negatywnego oddziaływania odpadowych wód hutniczych na główny ich odbiornik jest zdecydowanie mniejszy w przypadku huty Bolesław.

W odróżnieniu od środowiska lądowego zanieczyszczenie wód płynących metalami ciężkimi rozproszonymi z tego rodzaju hut nie jest zjawiskiem lokalnym. Metale ciężkie dostające się do rzeki migrują z wodą na znaczne odległości i obniżają jej klasę czystości w obrębie dużych obszarów. Stopień rozprzestrzenienia się metali w rzece zależy nie tylko od ładunku mineralnych zanieczyszczeń do niej zrzucanych, lecz także od właściwości chemicznych jej wody i charakteru koryta. Stosunkowo daleka migracja niektórych metali ciężkich w rzece Małej Panwi wiąże się między innymi także z dużą zawartością w wodzie tej rzeki rozpuszczonych związków organicznych, które mogą tworzyć z tymi metalami dłużej utrzymujące się w wodzie związki kompleksowe.

Zawartość materii organicznej w osadach rzeki Małej Panwi ze względu na przewagę w wodzie rozpuszczalnych związków organicznych i znaczną jej prędkość przepływu nie wykazuje korelacji z ilością materii organicznej doprowadzonej ze ściekami ani też przestrzennym rozmieszczeniem źródeł tych ścieków.

Klasę czystości wody potoku Stoła i rzeki Małej Panwi na odcinku od ujścia tego potoku do zbiornika Turawa (50 km) obniża, oprócz dużej ilości substancji organicznych, przede wszystkim wyjątkowo wysoka i rzadko stwierdzana w innych silnie zanieczyszczonych wodach zawartość kadmu. Woda tych cieków nie powinna więc być wykorzystywana do picia, jeśli w klasyczną technologię jej uzdatniania nie zostaną wprowadzone zabiegi skutecznie usuwające metale ciężkie. Ostatnio,

obok rtęci i ołowiu większe stężenia kadmu w środowisku są uważane za groźną truciznę dla wielu organizmów, zwłaszcza dla ssaków. Elementem sprzyjającym oczyszczaniu się wody rzecznej z metali ciężkich jest obecność na rzece zbiornika zaporowego. Dopływ zanieczyszczeniowych mikroelementów do wodociągowego zbiornika w Kozłowej Górze mieści się na razie jeszcze w zakresie takich wartości, które uważa się jedynie za czynnik eutrofizujący środowisko. W osadach dna badanych środowisk wodnych więcej mikroskładników akumuluje się w okresie letnim niż zimowym.

REFERENCES

- Abdullah M. J., L. G. Royle, 1972. Heavy metal content of some rivers and lakes in Wales. *Nature*, 238, 329—330.
- Bowen H. J. M., 1966. Trace elements in Biochemistry. New York, Acad. Press.
- Brooks R. R., B. F. Quin, 1971. Heavy metals in stream sediments of the Port Pegasus area of a Stewart Island. *New Zealand J. Sci.*, 14, 1, 25.
- Collective work, 1968. Role of soils and sediment in water pollution control. Part I. Southeast water laboratory FWPCB, US Dept. of the Int.
- Collective work, 1973. Standards für Schwermetalle in Wasser. *Wasser, Luft u. Betrieb.*, 6, 196.
- Collienne R. H., J. C. de Graeve, 1973. Agressivité des eaux vis à vis du plomb et contamination alimentaire dans l'est de la Belgique. *La Techn. de l'Eau*, 315, 17—28.
- Cottene A., 1972. Effect of soil enrichment with mineral elements and fertilizers on surface water and plants. *Soil Bull.*, 16, 343—356.
- Cowgill N. M., 1970. The hydrochemistry of Linsey Pond, North Brandford, Connecticut. 1. Introduction, field work and chemistry by X-ray emission spectroscopy. *Arch. Hydrobiol.*, 68, 1—95.
- Ebner F., H. Gams, L. T. Ottendorfer, 1972. Die Bestimmung von Schwermetallen in Österreichischen Oberflächengewässern. *Oesterr. Abwasser Rundsch.*, 4, 53—60.
- Gaudet J. J., 1973. Growth of a floating aquatic weed, *Salvinia* under standard conditions. *Hydrobiol.*, 41, 77—106.
- Gliński J., A. Grajpel, 1965. Zastosowanie metody przesypu oraz jednego dodatku w spektralnej analizie gleb. *Chemia Anal.*, 10, 681—686.
- Golwer A., W. Schneider, 1973. Belastung des Bodens und des unterirdischen Wassers durch Strassenverkehr. *Das Gas- u. Wasserfach*, 4, 154—165.
- Gregor C. D., 1972. Solubilization of lead in lake and reservoir sediments by NTA. *Environ. Sci. Technol.*, 6, 278.
- Greszta J., S. Godzik, 1969. Wpływ hutnictwa cynku i ołowiu na gleby. *Rocz. Glebozn.*, 20, 195—214.
- Hellmann H., 1972. Herkunft der Sinkstoffablagerungen in Gewässern (2. Mitteilung: Überlegungen und Ergebnisse aus der Sicht der Abwassertechnik). *Deutsche Gewässerk. Mitt.*, 16, 137—145.
- Jennet J. C., B. G. Wixson, 1972. Problems in lead mining waste control. *J. Wat. Poll. Contr. Fed.*, 44, 2103—2110.
- Kainz G., G. Böhm, F. Schöller, 1973. Über den Schwermetall-Gehalt von Schneeproben, Grund- und Oberflächengewässern. *Gas, Wasser, Wärme*, 4, 84—88.
- Karbe L., 1972. Marine Hydroiden als Testorganismen zur Prüfung der Toxizität von Abwasserstoffen. Die Wirkung von Schwermetallen auf Kolonien von *Eirene viridula*. *Marine Biol. Intern. J. on Life Oceans and Coastal Waters*, 12, 316—328.
- Kopp J. F., R. O. Kroner, (undated). Trace metals in waters of the United States. A five year summary of trace metals in rivers and lakes of the United States (Oct. 1, 1962 — Sept. 30, 1967) US Dept. of the Int., FWPCA, Cincinnati, Ohio.
- Kowaliński S., A. Bogda, J. Borkowski, T. Chodak, J. Drodz, M. Licznar, E. Roszyk., 1972. Wstępne badania nad wpływem zanieczyszczeń przemysłowych huty miedzi „Legnica” na zmiany niektórych właściwości gleb. *Kom. XIX Ogól. Zjazdu Nauk. PTG, Katowice-Kraków*, 296—304.

- Laubenberger G. L., L. Hartmann, 1971. Storage of heavy metal salts in bottom deposits of rivers and their effect on the Biocenose of Mud. *Wasserwirtsch.*, 60, 372.
- Lehman G. S., L. G. Wilson, 1971. Trace element removal from sewage effluent by soil filtration. *Water Resour. Res.*, 7, 90—99.
- Lobčenko E. E., V. T. Kaplin, 1968. Rol vzvešenných veščestv v samoočiščenii prirodnych vod od ionov medi i cinka. *Gidrochim. Mat.*, 48, 151—155.
- Malanchuk J. L., G. K. Gruending, 1973. Toxicity of lead nitrate to algae. *Water, Air and Soil Pollut.*, 2, 181—190.
- Mathis B. J., T. F. Cummings, 1973. Selected metals in sediments water and biota in the Illinois River. *J. Water Poll. Contr. Fed.*, 45, 1573—1594.
- Paluch J., S. Karweta, 1970. Imisja cynku i ołowiu w otoczeniu kombinatu hutniczego i jej oddziaływanie na rośliny i gleby. *Ochrona Powietrza*, 4, 6, 20.
- Pasternak K., A. Antoniewicz, 1969. Wstępne badania nad zawartością niektórych mikro-składników w wodach powierzchniowych południowej Polski— Preliminary investigations on the content of some trace components in surface waters of Southern Poland. *Acta Hydrobiol.*, 12, 111—124.
- Pasternak K., 1971. Zawartość miedzi, cynku i manganu w wodzie zbiornika zaporowego w Goczałkowicach oraz kilku innych zbiorników — The content of copper, zinc and manganese in the water of the dam reservoir at Goczałkowice and of several other reservoirs. *Acta Hydrobiol.*, 13, 159—177.
- Pasternak K., J. Gliński, 1972. Występowanie i kumulacja mikro-składników w osadach dennych zbiorników zaporowych południowej Polski — Occurrence and accumulation of microcomponents in bottom sediments of dam reservoirs of Southern Poland. *Acta Hydrobiol.*, 14, 225—255.
- Pasternak K., 1973. Rozprzestrzenienie metali ciężkich w wodach płynących w rejonie występowania naturalnych złóż oraz przemysłu cynku i ołowiu — The spreading of heavy metals in flowing waters in the region of occurrence of natural deposits and of the zinc and lead industry. *Acta Hydrobiol.*, 15, 145—166.
- Pasternak K., 1973 a. Występowanie i zmienność mikroelementów w wodzie w podłużnym przekroju rzeki Nidy — The occurrence and variability of microelements in the water in the longitudinal section of the river Nida. *Acta Hydrobiol.*, 15, 357—378.
- Pasternak K., 1974. Akumulacja metali ciężkich w osadach dennych rzeki Białej Przemszy jako wskaźnik ich rozprzestrzenienia drogą wodną z górniczo-hutniczego ośrodka przemysłu cynku i ołowiu — The accumulation of heavy metals in the bottom sediments of the River Biała Przemsza as an indicator of their spreading by water courses from the centre of the zinc and lead mining and smelting industries. *Acta Hydrobiol.*, 16, 51—63.
- Pasternak K., R. Turski, S. Baran, 1974. Zawartość mikroelementów w osadach dennych i wodzie rzek Przemszy i Wisły na odcinku ich najsilniejszego zanieczyszczenia — Trace element content in the bottom sediments and water of the rivers Przemsza and Vistula in the section of its most intense pollution. *Ochrona Przyr.*, 39.
- Robbins J. A., E. Landström, M. Wahlgren, 1973. Tributary inputs of soluble trace metals to Lake Michigan. *Great Lakes Res. Div.*, 4, 192—212.
- Shimp N. F., J. A. Schleicher, R. R. Ruch, D. Heck, H. V. Leland, 1971. Trace element and organic carbon accumulation in the most recent sediments of southern Lake Michigan. *Environ. Geology Not.*, 41, Illinois State Geol. Surv.
- Skawina T., T. Wąchałewski, 1965. Pierwiastki śladowe w glebach Górnośląskiego Okręgu Przemysłowego. *Biul. Zakł. Bad. Nauk. GOP PAN*, 5.
- Skawina T., 1967. Charakterystyka zmian glebowych wywołanych przez zanieczyszczenie powietrza w Górnośląskim Okręgu Przemysłowym. *Zesz. Nauk. Akad. Gór.-Hutn. w Krakowie*, 155, *Zesz. specj.*, 12, 233—248.
- Skei J. M., N. B. Prince, S. E. Calvert, 1972. The distribution of heavy metals in sediments of Sörfjord, West Norway. *Water, Air and Soil Poll.*, 1, 452—461.

- Standard Methods for the Examination of Water and Wastewater, 1971. 13th edition, Washington, APHA.
- Tucker A., 1972. The toxic metals. Earth Island, Ltd.
- Turski R., S. Baran, 1972. Wpływ hutnictwa cynku na zawartość mikroelementów w glebach i roślinach. Kom. XIX Ogól. Zjazdu Nauk PTG, Katowice-Kraków, 286—295.
- Wentink G. R., J. E. Etzel, 1972. Removal of metal ions by soil. J. Water Poll. Contr. Fed., 44, 1561—1574.
- Winchester J. W., G. D. Nifong, 1973. Water pollution in Lake Michigan by trace elements from pollution aerosol fallout. Repr. by perm. Great Lakes Res. Div., 4, 351—365.
- Wysokińska E., T. Różycka, W. Kudela, 1963. Stan zanieczyszczenia rzeki Stoły. Prace Inst. Gosp. Wod., 2, 63—115.
- Zajączkowska-Stęplowska A., 1972, Wpływ niektórych soli miedzi, niklu i kadmu na procesy oczyszczania ścieków osadem czynnym. Gaz, Woda i Tech. Sanit., 46, 5, 151—154.

Adres autora — Author's address

doc. dr hab. Kazimierz Pasternak

Zakład Biologii Wód, Polska Akademia Nauk, ul. Sławkowska 17, 31—016 Kraków