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Changes in selected environmental and biocenotic parameters of a polluted section of the Upper Vistula in the vicinity of the Łączany water stage (Southern Poland)

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Abstract — The investigation was carried out from 1977—1979 and 1981—1982 in the periods May—November at medium water level. The effect of the water stage on the self-purification processes of the water was studied on the basis of selected physico-chemical and biological properties. The results obtained showed that, apart from the improved oxygen conditions, increased amounts of suspension and a more abundant development of periphyton the stage did not bring about any distinct or directed changes in the water quality.

Key words: rivers, water stage, pollution, self-purification, periphyton.

1. Introduction

For many years the Institute of Environmental Development has been engaged in research on the problems of water protection and water--sewage management in the basin of the Upper Vistula. The general programme of investigations carried out and coordinated by the Institute was presented by Mańczak (1979). In 1976 the Kraków Branch of the Institute began project studies and research on the River Vistula in the Kraków region by elaborating the problem of the effect on water quality of the canalization of the river. The study was continued by an investigation on "The effect of the water stage damming the Upper Vistula on the course of self-purification processes (on the example of the Łączany water stage)" (unpublished materials).

The aim of the present work was to investigate the physico-chemical and bacteriological properties of the water and the quantitative and qualitative composition of epiphytic associations and to determine the effect of the water stage on the course of self-purification processes in the Vistula.

2. Study area

The Łączany damming stage has 5 sectors with overflow sluice-gates which regulate the magnitude of the water flow from the area of flood waters to the Vistula riverbed. In periods of higher water level all sluice-gates are closed while at medium and medium-low-level, when the investigation was carried out, 2 of the 3 sluice-gates were open. Samples were collected from the bank to which the main water flow was directed (fig. 1).

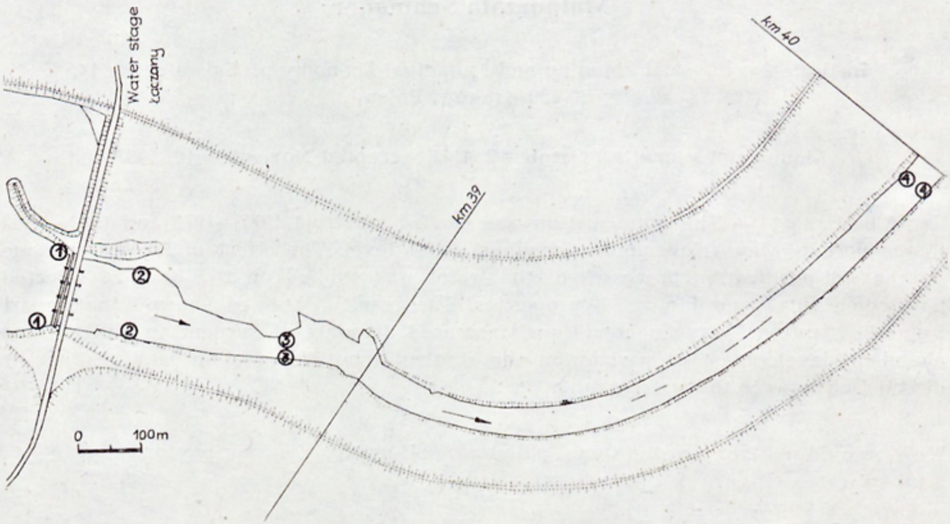

Fig. 1. General locale of the River Vistula in the vicinity of the water stage at Łączany (1—4 sampling stations)

Station 1 — the final part of the flood waters about 50 m above the stage, laminar water flow, at the banks the water 1—2 m in depth. The two banks lined with silted up calcareous boulders.

Station 2 — about 100 m below the stage; the flow turbulent, at a rate of about 2.4 m sec^{-1}. Depth of the water to 1 m. The riverbed broad, banks covered with large calcareous stones, between them muddy-sandy shoals.

Station 3 — about 250 m below the stage. Here the rate of flow was observed to decrease to 0.66—0.83 m sec^{-1}; the riverbed narrowed and depth increased to 2—3 m. The left bank was covered with silted up calcareous stones while the right one was muddy-sandy, with cobbles.

Station 4 — about 1500 m below the Łączany stage. Width and depth of the river as at Station 3. The water flow slightly slower: 0.63—0.78 m sec^{-1}. The steep banks muddy-stony.

3. Material and method

Samples for analysis were collected from 1977—1979 and 1981—1982 in the periods May—November at medium and medium-low (209.3—209.6 m above sea level) water level. The rate of flow was measured using a hydrometric flow method (Dynowska, Tlałka 1982). A total of 32 series of analyses were carried out: in 1977 — 8 series, 1978 — 6, 1979 — 10, and in 1981 and 1984 — 4 series each. One sampling from all stations was treated as an investigation series. Water samples for physico-chemical analysis were collected from a depth of 20 cm. The temperature of the water was measured at the surface and at Station 1 also at a depth of 0.50 m. Analyses were carried out in two repetitions, only oxygen being determined in 3 repetitions. The following water properties were investigated: temperature, pH, dissolved oxygen (in the vertical cross-section, using an oxygen sounder and the Winkler method), BOD_2, BOD_5, COD (dichromate and from autumn 1981 also permanganate), free CO_2, phosphates, ammonia and nitrate nitrogen, chlorides, sulphates, suspension, total iron, number of psychrophilic and mesophilic bacteria and faecal coliform titre.

Samples of periphyton were taken from a depth of about 5—10 cm throughout the period of investigation and in 1979, 1981, and 1982 also at a depth of 40—50 cm. Samples from the smaller depth were usually obtained by washing stones, more rarely sub-samples being collected from the upper layer of mud. Stones or mud from the greater depth were taken with a bottom scraper covered with a 55 μ mesh net. The investigated material was collected from an area of about 100 cm^2 and diluted in 100 cm^3 of water. Part of the sample was examined *in vivo* and the rest was fixed. For the identification of diatoms solid slides were made in pleurax. The qualitative composition was determined on the basis of 3 slides (3×0.5 cm^3). Depending on the density of the material, algae and other micro-organisms were counted in 1—10 strips or 10 fields of vision of 3 slides. Only live algae with an undameged chloroplast were counted and the occurrence of empty diatom shells or other damaged algae was only recorded in the list of species. In the case of filamentous blue-green and green algae one filament or ramule was taken as a unit and in evaluating the size of zoogleal associations and colony forms the area of 1 square of the eyepiece with the graticule was used. In order to obtain comparable results the quantitative data were converted to an area of 1 strip of the slides (about 10 mm^2).

4. Results

4.1. Physico-chemical characteristics

The diel thermic lamination in the flood waters occurred above the Łączany stage (Station 1). At noon the water temperature at the surface was higher by 2—4°C in summer and lower by 1—2°C in late autumn than at a depth of 0.5 m. The measurements showed that the two water layers became mixed when flowing over the stage, hence at stations

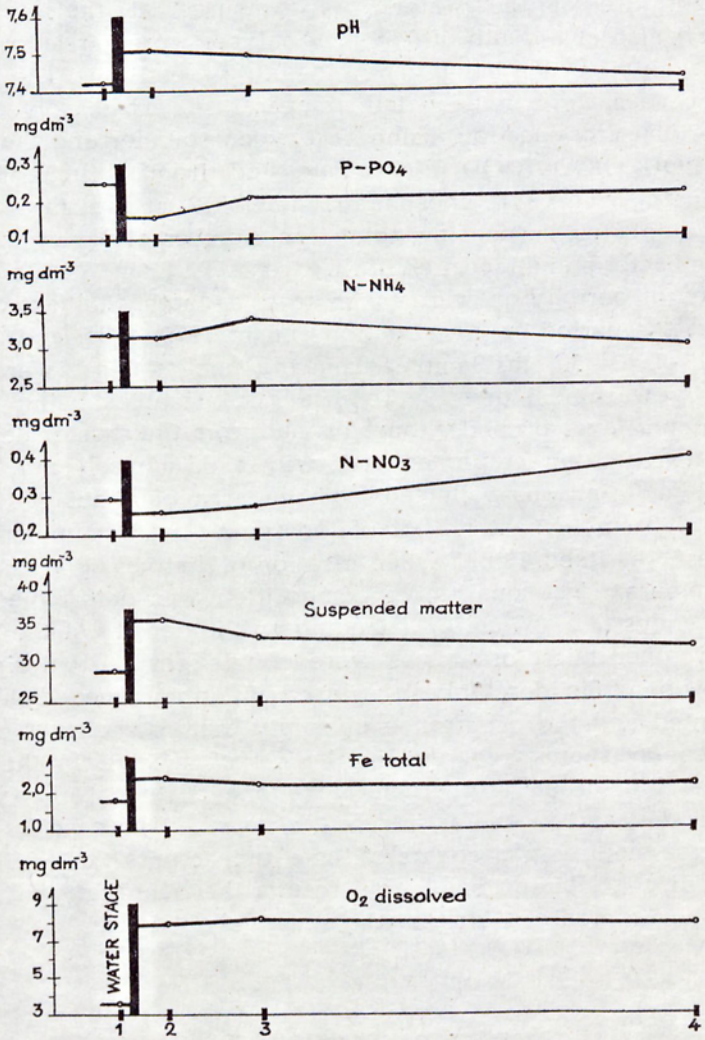

Fig. 2. Physico-chemical properties of the water at Stations 1—4 (mean values from 1977—1979 and 1981—1982)

below the stage the water was cooler in summer and slightly warmer in late autumn than at Station 1 (differences of about 0.5—1.0°C).

The pH value of the water flowing to the stage (Station 1) approximated to neutral or was slightly alkaline (7.1—8.2, with the most frequent value of 7.4). The flow of water over the overflow crest caused and increase in the pH value by 0.1 on the average (fig. 2). This was associated with aeration of the water and a simultaneous decrease in the content of free CO_2.

At Station 1 the water was strongly salinated. The mean concentrations of chlorides exceeded the values permitted for water purity class III (ordinance of the Council of Ministers, November 29, 1975). In the period of investigation a tendency to increasing water salinity was observed (mean values of mg Cl dm^{-3}: 1977—1978 = 500, 1979—1980 = 460, 1981 = = 540, 1982 = 620). The obtained analytical data show that the water stage did not in any directed affect the concentration of chlorides and sulphates (Table I) and the peridical differences were probably associated with the occurrence of more or less salinated water in the flood waters.

The water flowing to the stage contained considerable amounts of biogenic elements. Phosphate content varied from 0.05—0.63 mg P—PO_4

Table I. Mean values of selected chemical parameters at Stations 1-4 for characteristic periods from 1977-1979 and 1981-1982.
— - not investigated

Date of study	Station	Oxygen saturation %	BOD_5 mg O_2 dm^{-3}	COD mg O_2 dm^{-3}	Chlorides mg Cl dm^{-3}	Sulphates mg SO_4 dm^{-3}
1977 30.VIII - 12.XI	1	31.9	4.0	34.9	314	145
	2	80.3	5.1	44.0	344	153
	3	90.6	4.9	53.2	343	150
1978 3.V - 27.V	1	45.6	2.6	30.4	496	134
	2	89.3	6.1	25.8	468	127
	3	81.0	4.8	41.2	447	113
1978 6.VI - 20.VI	1	27.6	12.5	26.5	447	139
	2	82.6	10.9	25.0	468	149
	3	79.9	8.8	29.4	525	144
1979 14.V - 29.VI	1	42.2	7.8	41.5	560	169
	2	74.1	7.5	40.2	625	148
	3	78.5	6.6	37.2	585	159
	4	71.4	5.7	39.1	-	-
1979 27.VIII - 24.X	1	15.5	9.5	31.0	590	156
	2	69.7	7.4	32.0	579	154
	3	76.2	7.3	32.7	561	153
	4	79.6	6.6	32.2	-	-
1981 14.IX - 6.X	1	36.3	3.0	8.6	505	125
	2	79.2	3.2	8.0	575	124
	3	86.8	3.4	9.4	555	130
	4	82.0	3.1	10.0	545	128
1981 13.X - 26.X	1	45.6	3.0	12.5	460	138
	2	73.7	3.4	14.2	440	134
	3	86.2	4.9	14.0	430	134
	4	78.8	5.3	12.8	430	135
1982 5.V - 15.VI	1	22.1	3.0	14.8	733	154
	2	79.5	2.4	15.4	756	158
	3	82.6	3.9	14.2	702	153
	4	78.8	3.5	14.4	756	152

dm^{-3}, the concentrations of ammonia nitrogen from 0.7—11.4 mg $N—NH_4$ dm^{-3}, and of nitrate nitrogen from 0.3—0.72 mg $N—NO_3$ dm^{-3}. In most series the concentrations of phosphates and nitrates in the water decreased below the Łączany water stage (fig. 2). This probably resulted from the uptake of biogenic elements by abundantly developing epiphytic associations. The content of ammonia nitrogen in the water slightly increased below the stage or was maintained at a uniform level.

The Upper Vistula is among those rivers where the load of suspension exceeds the norm and which contain great amounts of iron compounds. In spite of the fact that the samples were only collected at medium or medium low water level the water flowing to the stage was turbid, poorly transparent, and heavily loaded with suspension (10—80 mg dm^{-3}). In most series of analysis an increase in the amount of suspension and iron compounds (fig. 2) was observed in the cross-sections below the stage. From analysis of the composition of suspension from the particular stations it was noted that volatile parts (organic suspension) showed a more distinct increase. It is supposed that at the stations below the stage increased pollution of the water with suspended matter was brought about by the scouring of sediments from strongly silted up and shallowed flood waters.

During the spilling of water over the crest of the stage abundant foam periodically appeared, patches of it being carried by the river current. In connection with this phenomenon data were collected concerning the concentrations of detergents (analyses of the Kraków Centre of Environmental Research and Control). The content of detergents did not exceed the values permitted for waters of purity class II, this suggesting that the foaming of the Vistula waters was caused by some other factors.

4.2. Oxygen conditions

At Station 1 the water was characterized by a considerable oxygen deficit and its O_2 saturation varied from 8—61%. By spilling over the crest the water was aerated, this being followed by a pronounced increase in oxygen saturation (by 21.6—66.3%) (Table I, fig. 3). The oxygen saturation of the water increased according to exponential curves and depended upon the magnitude of O_2 deficiency in the water flowing to the stage (fig. 3). The measurements carried out with an oxygen sounder in the vertical cross-section of Station 1 showed that the percentage of O_2 saturation decreased almost to nought in the layer near the bottom. At stations below the stage no such differences were found, while frequent changes in oxygen saturation of the water reached $\pm 25\%$. This may account for the phenomenon of a pronounced variability of oxygen saturation percentage at Stations 3 and 4 compared with Station 2 (Table I).

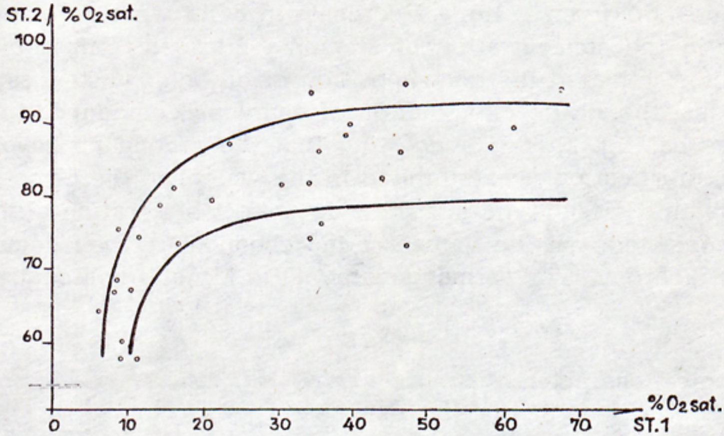

Fig. 3. Dependence between the initial percentage of oxygen saturation of the water (Station 1) and after aeration on the Łączany water stage (Station 2)

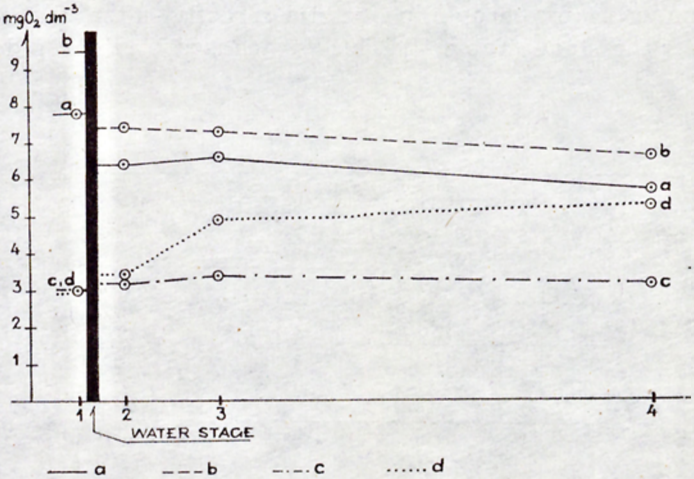

Fig. 4. Biochemical oxygen demand at Stations 1—4 in the periods a — spring 1979; b — summer-autumn 1979; c — early autumn 1981; d — October 1981

In the particular periods of the investigation there appeared a great variation in BOD_5, this preventing a general interpretation of results. Those from the particular periods showed that when the biochemical oxygen demand was 2.6—4.0 mg O_2 dm^{-3} in the water flowing in (Station 1) the value of this index increased or did not significantly change at Stations 2, 3, and 4. But when the BOD_5 varied from 7.2—21.6 mg O_2 dm^{-3} at Station 1, at Stations 2, 3, and 4 a decrease in this value followed, reaching 6.6—30.8%. Examples of a differentiated effect of the stage on

BOD_5 values are given in fig. 4. Decreases in BOD_5 were accompanied by increases in the concentration of ammonia nitrogen. This showed that the aeration activated the decomposition of organic substances containing nitrogen, though no oxygenation of ammonia compounds to nitrates was observed (fig. 2), this suggesting that the second phase of selfpurification, nitrification, was inhibited in the waters of the Upper Vistula.

The obtained results did not show any effect of aeration of the water at the water stage on the values of the chemical oxygen demand. The values of dichromate or permanganate COD did not significantly change (Table I).

4.3. Biological characteristics

4.3.1. Bacteriological properties

In the particular series there appeared a variation in the numbers of all groups of investigated bacteria. Averaged results show a decrease in the number of psychrophilic bacteria directly after the spilling of waters over the stage (Table II). This was caused by the rapid change of

Table II. Mean numbers of bacteria and faecal coliform titre at Stations 1-4

Year of study	Station	Number of bacteria: psychrophilic (20°C, 72 h) $n \cdot 10^3$ cm^{-3}	Number of bacteria: mesophilic (37°C, 24 h) $n \cdot 10^3 cm^{-3}$	Faecal coliform titre
1977	1	2322.2	81.7	$2 \cdot 10^{-3} - 5 \cdot 10^{-5}$
	2	1656.8	169.2	$2 \cdot 10^{-3} - 4 \cdot 10^{-6}$
	3	2082.6	184.4	$2 \cdot 10^{-3} - 1 \cdot 10^{-5}$
1978	1	100.7	49.1	$1 \cdot 10^{-2} - 1 \cdot 10^{-3}$
	2	97.3	61.8	$1 \cdot 10^{-2} - 1 \cdot 10^{-3}$
	3	628.0	54.8	$1 \cdot 10^{-2} - 1 \cdot 10^{-4}$
1979	1	678.3	39.2	$5 \cdot 10^{-2} - 2 \cdot 10^{-4}$
	2	424.5	58.4	$1 \cdot 10^{-2} - 6 \cdot 10^{-5}$
	3	806.0	53.2	$1 \cdot 10^{-2} - 8 \cdot 10^{-5}$
	4	748.2	46.8	$2 \cdot 10^{-2} - 6 \cdot 10^{-5}$
1981	1	116.5	12.2	$2 \cdot 10^{-2} - 5 \cdot 10^{-4}$
	2	107.0	32.7	$4 \cdot 10^{-3} - 8 \cdot 10^{-5}$
	3	146.5	18.6	$2 \cdot 10^{-3} - 5 \cdot 10^{-5}$
	4	124.4	19.0	$4 \cdot 10^{-3} - 4 \cdot 10^{-6}$

environmental conditions. At Stations 3 and 4 the number of these bacteria again increased. Psychrophilic bacteria appear as the natural microflora of polluted waters and their more abundant development is regarded as a phenomenon favourable for self-purification processes.

The average number of mesophilic bacteria increased at the stations below the water stage. Also the values of the coliform titre illustrated the increased bacteriological pollution of the water. The results of analyses (Table II) showed that the stage did not improve the sanitary conditions of the Vistula waters.

4.3.2. Epiphytic associations

In epiphytic associations on the periphery of flood waters (Station 1) algae dominated in the period 1977—1979 while in 1981—1982 filamentous bacteria prevailed (Table III). Among epiphytic algae diatoms quantitatively dominated. The seasonal variation of their species composition was manifested throughout the investigation period. In spring the following species occurred and sometimes even dominated: *Diatoma elongatum* (Lyngb.) Ag. var. *tenue* (Ag.) V.H., accompanied by *D. elongatum* (Lyngb.) Ag. and *D. vulgare* Bory, *Nitzschia palea* (Kütz.) W. Sm., *N. palea* var. *tenuirostris* Grun., *Fragilaria construens* var. *subsalina* Hust., *Surirella ovata* Kütz., and representatives of the genus *Synedra*. However, in summer and autumn the above-mentioned species of the genus *Nitzschia* were most numerous and besides them there occurred *N. filiformis* (W. Sm.) Hust. and the genus *Navicula*. Apart from diatoms in the periphyton of this station green

Table III. Mean numbers (n) and percentage of the basic groups of microorganisms forming epiphytic associations at Stations 1–4 at a depth of 5–10 cm and at Stations 1'–4' at a depth of 40–50 cm. — - did not occur

Period of study	Station	Schizomycetes Myxomycetes		Cyanophyceae		Euglenaceae		Bacillariophyceae		Chlorophyceae		Other algae		Animal microorganisms	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%
Summer-Autumn 1977 30.VIII-12.XI	1	164	10.8	33	2.2	17	1.1	962	63.0	100	6.6	1	0.1	246	16.1
	2	1100	18.1	61	1.0	7	0.1	3509	57.7	1045	17.2	1	0.1	355	5.8
	3	1842	72.6	1	0.1	7	0.3	287	11.3	28	1.1	14	0.6	354	14.0
Spring 1978 3.V-20.VI.	1	532	14.2	504	13.5	25	0.7	2161	57.7	503	13.4	8	0.2	13	0.3
	2	2983	53.2	42	0.7	1	0.1	2248	40.0	131	2.3	25	0.4	183	3.3
	3	4431	82.2	1	0.1	1	0.1	747	13.9	72	1.3	–	–	130	2.4
Spring 1979 14.V-29.VI.	1	319	26.7	79	9.0	6	0.6	765	51.0	123	10.7	5	0.5	15	1.5
	1'	222	73.4	45	9.2	3	3.3	8	8.8	1	0.5	2	1.7	6	3.1
	2	1078	17.6	205	3.4	7	0.1	3922	64.1	825	13.5	18	0.3	61	1.0
	2'	2126	33.0	263	4.0	6	0.1	3972	53.4	682	8.8	4	0.1	40	0.6
	3	2027	77.2	96	2.9	6	0.2	448	16.0	63	2.0	4	0.1	37	1.6
	4'	3184	72.0	148	3.3	3	0.1	597	13.5	270	6.1	200	4.5	21	0.5
Summer-Autumn 1979 27.VIII-24.X.	1	1899	51.0	124	3.4	9	0.2	1514	41.8	109	3.0	4	0.1	19	0.5
	1'	1576	90.0	29	5.8	1	0.1	24	3.2	2	0.3	1	0.1	8	0.5
	2	4576	39.9	211	1.8	2	0.1	5623	49.0	1048	9.1	6	0.1	16	0.1
	2'	7576	71.0	259	2.4	1	0.1	1980	18.5	798	7.5	13	0.1	42	0.4
	3	3353	84.7	82	2.1	2	0.1	383	9.7	123	3.1	4	0.1	9	0.2
	4	2944	90.8	48	1.4	1	0.1	150	5.2	55	1.9	6	0.2	14	0.4
Autumn 1981 14.IX-26.X.	1	2875	69.2	43	0.7	1	0.1	900	22.2	284	6.7	2	0.1	45	1.0
	1'	1934	97.0	5	0.4	1	0.1	23	1.3	2	0.2	1	0.2	11	0.8
	2	1935	41.0	170	2.5	3	0.1	2278	44.1	655	11.0	13	0.4	35	0.9
	2'	4925	67.0	1020	13.9	1	0.1	1110	15.2	255	3.5	5	0.1	107	0.2
	3	3709	82.1	40	0.9	2	0.1	657	14.4	92	2.0	9	0.2	15	0.3
	3'	1668	92.9	3	0.2	3	0.2	105	5.8	12	0.6	3	0.1	4	0.2
	4	3884	93.2	2	0.1	2	0.1	256	6.0	5	0.1	3	0.1	15	0.4
	4'	1510	95.4	1	0.1	3	0.2	61	3.9	2	0.1	2	0.1	3	0.2
Spring 1982 5.V - 15.VI.	1	3011	61.1	54	1.0	15	0.3	943	18.9	796	18.4	–	–	12	0.2
	1'	3147	97.4	41	0.9	4	0.3	20	0.8	6	0.4	2	0.1	2	0.1
	2	1758	28.2	654	11.8	4	0.1	3276	51.4	514	8.3	4	0.1	6	0.1
	2'	4516	65.8	66	1.1	11	0.2	2246	30.0	162	2.5	10	0.2	17	0.2
	3	3942	61.6	5	0.1	45	0.7	1830	28.6	283	4.4	5	0.1	286	4.5
	3'	5108	89.0	10	0.2	50	0.9	25	0.4	25	0.4	–	–	519	9.1
	4	2894	54.7	14	0.3	26	0.5	1912	36.2	403	7.6	10	0.2	28	0.5
	4'	4001	86.4	14	0.3	15	0.4	520	11.7	13	0.3	6	0.1	36	0.8

algae of the genera *Ulothrix, Stigeoclonium, Cladophora, Mougeotia,* and *Spirogyra* were fairly numerous (Table III). Among blue-green algae *Phormidium autumnale* (Ag.) Gom. was most common. The qualitative composition and quantitative relations in epiphytic associations developing above the water stage (Station 1) were characteristic for slowly flowing, eutrophic, and mesotrophic rivers. The described qualitative and quantitative composition concerned only the narrow belt of riverside stones occurring within the range of lateral undulation. In samples taken at the same station but from a depth of about 40 cm (the average limit of transparency of the Vistula water) the number of algae distinctly decreased and bacteria (fig. 5) accompanied by blue-green algae began to dominate (Table III).

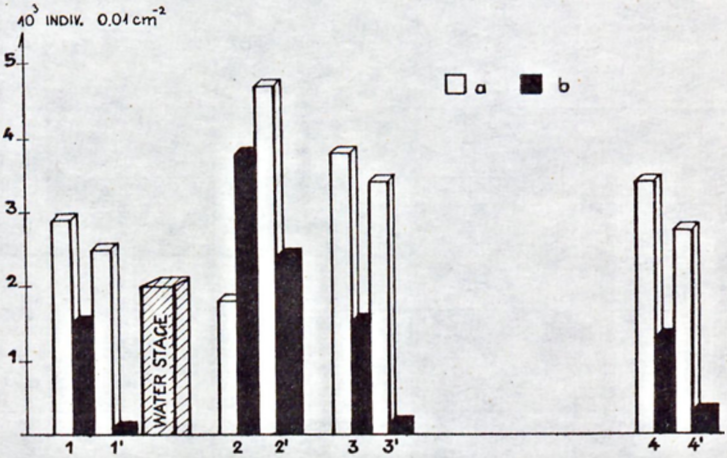

Fig. 5. Mean numbers of reducers (a) and producers (b) in epiphytic associations of the River Vistula at Stations 1—4 (samples from a depth of 5—10 cm) and at Stations 1'—4' (samples from a depth of 40—50 cm) in the years 1981 and 1982

At Station 2 (below the stage) the character of the flow changed rapidly and the oxygen saturation increased, this stimulating the development of epiphytic associations (Table III). Near the water stage stones were covered with noticeable agglomerations of algae and bacteria. The occurrence of unispecies patches of diatoms living in gelatinous tubes or agglomerations was frequently noted. Diatoms presented a variability similar to but not so distinct as that found at Station 1. Besides the species of diatoms recorded at Station 1, *Melosira varians* Ag., *Navicula viridula* Kütz., and *Gomphonema angustatum* var. *productum* Grun. were very numerous at some periods there. Among green algae *Stigeoclonium tenue* (Ag.) Kütz. and *Ulothrix,* determined as *subtilis* Kütz. and among blue-green algae species *Phormidium autum-*

nale (A g.) G o m. and *Gloeocapsa crepidinum* T h u r. were most numerous and most frequent. At Station 2 a very abundant development of epiphytic associations occurred in the whole riverbed. On stones taken from a depth of about 40 cm more bacteria were found than near the banks but algae were still very numerous (Table III, fig. 5). An increase in the numbers of bacteria and algae and the appearance of the samples showed that the epiphytic associations which developed at this station might intensively participate in the self-purification processes of the Vistula waters.

In spring samples from Stations 1 and 2 a predominance of β-mesosparobionts was found while in summer and autumn α-mesosaprobic species were more numerous. Most algae which developed abundantly in the periphyton belonged to mesahalophilic species or to these characteristic for water with an increased content of iron compounds.

At Stations 3 and 4 the impoverishment (Table III) and silting up of epiphytic associations were observed. Among algae the dominant species were the same as at Stations 1 and 2 but their numbers were distinctly reduced. The inhibition in the development of algae was most pronounced in summer and autumn. In samples taken from a depth of about 40 cm filamentous algae covered with a mud layer, zoogloeal agglomerations, and attached Ciliata, chiefly *Carchesium polypinum* L., were encountered almost exclusively. The silting up and impoverishment of epiphytic associations were regarded as unfavourable from the point of view of the self-purification of the water.

5. Discussion

It is generally considered that the building of dams across rivers is beneficial for self-purification processes on account of the aeration of the water flowing over their crest. This is very important in the case of canalized rivers, since their waters have a limited opportunity of atmospheric aeration. The damming of a river contributes to the sedimentation of suspension and mineral and organic fractions, and in consequence to the improvement of water quality. However, the accumulation of large amounts of sediments with a considerable content of organic matter causes an inadmissible deoxidation of the water, this resulting in the inhibition of self-purification processes. Some authors have also reported that the scouring of pollution accumulated in the sediments, deteriorated the properties of the water (L i e b m a n n 1961, K r e n k e l et al. 1965, M a ń c z a k 1972, I m h o f f, A l b r e c h t 1974, R o t h s c h e i n 1976).

The investigation in the vicinity of the Łączany water stage showed that the water spilling over the crest carried fine (slowly settling) suspension containing a fairly large fraction of organic matter. This was brought about by the strong silting up of the flood waters at the stage. The very intense processes of silting up of the Vistula riverbed near the Przewóz water stage in Kraków were described by Fiszer and Trela (1980).

The estimation of self-purification processes, based on oxygen conditions, confirmed the opinion that water stages contribute to a decrease in oxygen deficiency and demand. This is in agreement with data presented by Woyciechowska and Dojlido (1982). In accordance with the typology presented by those authors, the flood waters above the stage were classified as small shallow reservoirs of abundant flow fed with polluted water. An improvement in water quality below the water stages was described for this group of reservoirs in 86% of cases. Wróbel and Szczęsny (1983) reported that the damming of the Vistula at Łączany improved the quality of the river water but they remarked that within the impounded waters the conditions were more critical than in the river above the stage. They based this conclusion on the investigation of Bombówna and Wróbel (1966). Their analyses did not include the stations below the water stage, thus making it impossible to compare them with the analytical results presented here.

The data obtained in the 5-year study show that only oxygen conditions decisively improved below the stage. No directed or distinct changes in water salinity, concentrations of biogenic elements, or other basic properties of the water could be observed; neither did the improvement of oxygen conditions affect the activation of nitrification processes. These results agree with the description given by Woyciechowska and Dojlido (1982) and Wróbel and Szczęsny (1983). The Łączany water stage also had a deteriorative effect on the water quality, as was manifested by the appearance of foam patches, an increased amount of suspension, decreased water transparency, periodical increases in BOD_5 and in the content of iron compounds, and the deterioration of sanitary conditions of the water.

The hydrobiology of the investigated sector of the Vistula was previously elaborated by Kyselowa and Kysela (1966) and Hanak-Schmager (1974). The species composition of attached algae and the quantitative relations have not decisively changed since that time. In the zone of the turbulent fall below the stage there appeared a very abundant development of algal-bacterial epiphytic associations. These associations are a particularly active part of the biocenosis (Bombówna 1972), contributing to the rapid self-purification of the water in the upper course of rivers. At Stations 3 and 4 where the character of the Vistula approximates to that of canalized rivers, the impoverishment and silting up of epiphytic associations were observed. Hence, it was concluded that the damming of the river eliminated shallow fragments with an abundant and varied flora of attached algae, decreased the rate of water flow (Wuhrman 1975), and in consequence considerably limited the purification and biological oxygenation of the water, thereby favouring the mass development of seston algae (Praszkiewicz et al. 1983, Schmager 1986). Phytoplankton constitutes a biocenotic of much poorer activity than the periphyton, since it contains less chlorophyll (Wróbel, Szczęsny 1983) and only slightly increases the content of oxygen in the water (with the number of algae reaching 9 thousand specimens in 1 cm^3 the diel balance of O_2 content is about $+0.2$ mg O_2 dm^{-3} — Knopp 1959). Moreover, the mass development of phytoplankton is commonly regarded as an unfavourable phenomenon (Wiśniewski 1958, Kajak 1979, Praszkiewicz et al. 1983).

In spite of the fact that the present study concerned only one damming water stage, an element of hydrotechnical construction which usually improves the properties of canalized rivers, it confirmed the suggestions of Mańczak et al. (1979), Turoboyski and Pudo (1979), and Schmager (1985) that the cascade under construction on the Upper Vistula would bring about a decrease in the self-purification ability of the river.

6. Polish summary

Zmiany wybranych parametrów środowiskowych i biocenotycznych zanieczyszczonego odcinka Górnej Wisły w rejonie stopnia wodnego Łączany (Polska Południowa)

Badania prowadzono w latach 1977—1979 i 1981—1982, w okresach od maja do listopada, przy średnich i średnich-niskich stanach wody. Badano własności fizyczno-chemiczne, bakteriologiczne oraz skład jakościowy i ilościowy zespołów poroślowych, na czterech stanowiskach w rejonie stopnia Łączany (38.5—40,0 km biegu rzeki, ryc. 1). Próby peryfitonu pobierano przy powierzchni wody oraz z głębokości ok. 40 cm.

Wyniki analiz fizyczno-chemicznych wykazywały, że stopień wodny nie powodował istotnych lub ukierunkowanych zmian większości wskaźników jakości wody (ryc. 2, tabela I). Stwierdzono natomiast, że woda poniżej stopnia zawierała większe ilości zawiesiny, żelaza (ryc. 2) oraz że pogorszeniu uległy jej własności sanitarne (tabela II). Przelewająca się przez koronę stopnia woda silnie się napowietrzała (wzrost nasycenia wody tlenem o 21,6—66,6%). Powodowało to obniżenie się biochemicznego zapotrzebowania tlenu (w przypadkach, gdy BZT_5 wody dopływającej było wyższe od 4,0 mg O_2 dm^{-3}, ryc. 4). Na podstawie własności tlenowych oceniono, że napowietrzanie uaktywnia przebieg I fazy samooczyszczania się wody, nie stwierdzono natomiast, aby uaktywniało procesy II fazy samooczyszczania — nitryfikacji. Badania hydrobiologiczne wykazały, że na stanowisku 2 ok. 100 m poniżej stopnia nastąpił bardzo bujny rozwój glonowo-bakteryjnych zespołów poroślowych sprzyjających samooczyszczaniu się wody. Na dalszych stanowiskach obserwowano jednak zubożenie i zamulenie peryfitonu, szczególnie wyraźne w przypadku prób pobieranych z większej głębokości (tabela III). Rozwijające się masowo glony osiadłe należały do gatunków słonawowod-

nych, co świadczy o wyraźnym wpływie wysokich stężeń chlorków na kształtowanie się zespołów poroślowych Górnej Wisły.

Prezentowane wyniki dotyczyły tylko oddziaływania stopnia piętrzącego, elementu zabudowy hydrotechnicznej zazwyczaj sprzyjającego samooczyszczaniu się wody. Badania wykazały jednak, że stopień wpływał również i negatywnie na własność wody. Zarówno wyniki niniejszej pracy, jak i dane zawarte w literaturze, wskazują, że realizowana zabudowa kaskadowa Wisły spowoduje pogorszenie jakości wody i ograniczenie rozwoju zespołów poroślowych — części biocenozy szczególnie aktywnej w samooczyszczaniu się rzeki.

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