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## CHANGES IN THE QUALITY OF WATER FROM THE SOLINA AND MYCZKOWCE DAM RESERVOIRS FROM 1971 TO 1990

The purpose of the paper is to define the changes in the quality of water from the Solina and Myczkowce dam reservoirs on the basis of their physicochemical properties. It has been proved that the quality of water in these reservoirs deteriorated. The poor quality of water is evidenced by an increase in bacteriological impurities and turbidity as well as concentrations of phosphates, iron, magnesium, calcium, chlorides and sulphates. The water quality did not change during the whole investigation period at the E/S sampling point upstream from the Solina dam.

### 1. INTRODUCTION

The Solina and Myczkowce dam reservoirs on the River San (fig. 1) are arranged in a series of cascades. The Myczkowce reservoir was launched in 1961 as a retarding reservoir for the water-power plant at Myczkowce, while the Solina reservoir in 1968 as a retarding reservoir for the pumped-storage power station at Solina. The maximum capacities of the Myczkowce and Solina reservoirs are 10.2 and 502.0 million m<sup>3</sup>, respectively. Other technical and hydrological characteristics of both reservoirs are given in papers [1], [2]. The reservoirs, except for their retention and energetic role, are used as sources of drinking water for the nearby towns and villages.

In 1971-1972, the investigations allowing us to assess the quality of water in both reservoirs and to choose the best location for the intake of water to be used by the timber plant at Ustianowa and by the town of Ustrzyki Dolne together with the adjoining hamlets were initiated at the Technical University of Rzeszów.

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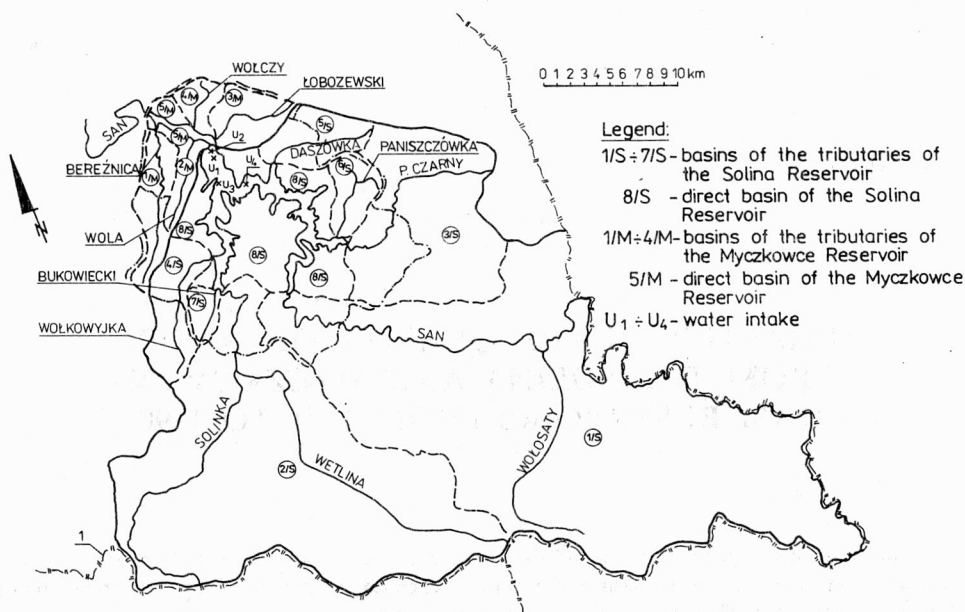


Fig. 1. Basins of the Solina and Myczkowce dam reservoirs and their tributaries

In these investigations, use was made of the results of the water quality control carried out in the laboratories of the Environmental Research and Control Centre in Rzeszów and Jasło.

## 2. METHOD OF INVESTIGATIONS

The investigations were carried out according to research programme [3], instructions [4], [5], Polish Branch Standards [6] and literature [7]. Sampling points were selected along the seven main tributaries of the Solina reservoir and four main tributaries of the Myczkowce reservoirs, as well as at six (Solina) and three (Myczkowce) places typical of the configuration of the two reservoirs (fig. 2). The sampling points were chosen in such a manner that location of main tributaries, sources of impurities, bank development and work of water-power plants at Solina and Myczkowce were taken into account. At the points chosen, samples of water were taken at the depths of 0.2, 1, 3, 5, 7, 10 m as well as 5 m and 1 m above the bottom at varying frequency, 3-6 times a year.

The investigations were carried out to determine 41 physicochemical and 4 bacteriological indicators of the water quality. Besides, hydrobiological investigations of the natural and network systems as well as the periphyton were conducted.

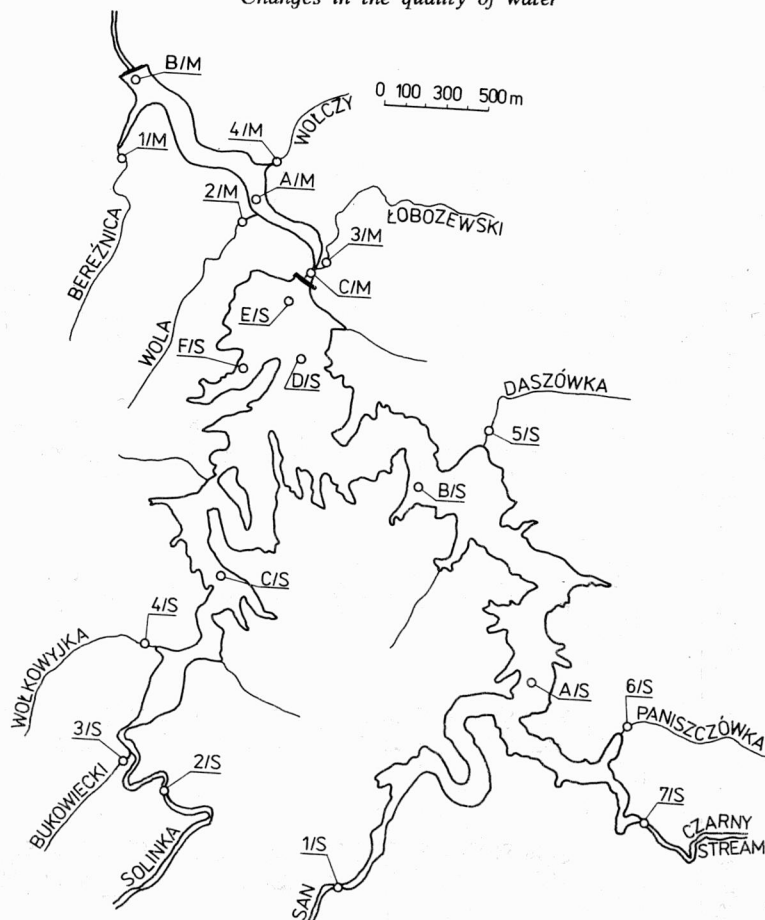


Fig. 2. Sampling points at the Solina and Myczkowce reservoirs

### 3. CHANGES IN WATER QUALITY

In order to determine the water quality in both reservoirs, results collected during the twenty-years' period were divided into four five-year sets of data representing each sampling point separately and all the sampling points summarily. 21 more important indicators were analysed taking account of those which exceeded the permissible values characterizing the 1st class of water purity. Maximum and medium concentrations of some indicators were also analysed. Cumulative data for the Solina and Myczkowce reservoirs concern four five-year periods (tables 1 and 2).

In the second five-year period of twenty-years' investigations, the quality of water in the Solina reservoir improved with respect to colour, suspension, BOD and nitric compounds.

## Quality of water in the Solina reservoir during 1971-1990

Indicator	Max (g/m <sup>3</sup> )				Number of analyses			
	Average (g/m <sup>3</sup> )				Percentage of values higher than those for 1st class			
	Time				Time			
	1971-1975	1976-1980	1981-1985	1986-1990	1971-1975	1976-1980	1981-1985	1986-1990
Colour, Pt	50.00	22.00	35.00	40.00	794	255	220	230
	11.13	9.34	9.21	16.53	10.96	1.96	2.27	43.91
Smell	3.00	5.00	5.00	5.00	576	255	240	240
	1.13	1.61	2.66	2.35	0.00	0.39	5.83	10.38
Turbidity	60.00	45.00	15.00	25.00	772	255	220	240
	6.77	8.94	5.79	6.10	-	-	-	-
Suspended solids	110.0	17.00	15.70	21.45	764	73	211	240
	9.77	8.80	3.62	3.41	10.99	0.00	0.00	0.42
pH	8.80	8.60	8.70	8.96	910	255	240	240
	7.89	7.93	7.97	7.97	30.99	26.27	38.75	45.00
Calcium	62.80	46.28	61.25	54.14	447	52	239	240
	31.01	35.05	35.50	36.72	-	-	-	-
Iron	1.20	1.01	0.85	1.14	782	255	216	240
	0.07	0.12	0.11	0.16	0.26	0.39	0.00	0.42
Magnesium	23.58	20.89	30.48	31.31	415	52	240	238
	7.07	10.10	10.28	9.32	-	-	-	-
Sulfates	47.40	94.10	141.0	58.40	764	255	232	240
	17.49	31.28	32.59	31.05	0.00	0.00	0.00	0.00
Chlorides	20.00	28.30	25.00	26.00	783	255	230	240
	6.85	9.92	7.80	7.61	0.00	0.00	0.00	0.00
Dissolved oxygen	14.40	13.10	12.00	11.05	953	254	192	240
	9.52	9.03	8.61	7.76	1.68	5.12	3.12	12.5
BOD	8.60	3.10	2.60	3.00	945	255	220	240
	1.79	1.62	1.56	1.66	0.42	0.00	0.00	0.00

Oxygen consumption	11.50	8.50	5.10	5.80	786	245	134	240
	2.82	2.99	2.98	3.18	0.13	0.00	0.00	0.00
Ammonia nitrogen	0.500	1.200	0.600	0.598	775	243	230	240
	0.025	0.075	0.103	0.148	0.00	0.40	0.00	0.00
Nitrates	8.300	2.670	4.350	2.704	765	253	240	240
	1.246	0.723	1.120	1.399	34.90	14.23	9.17	35.0
Nitrogen	0.080	0.080	0.090	0.200	786	255	240	240
	0.017	0.008	0.017	0.016	-	-	-	-
Organic nitrogen	5.600	1.300	1.984	3.040	774	235	240	240
	0.723	0.551	0.750	1.258	20.67	4.68	25.0	68.75
Total phosphorus	4.90	1.50	2.60	0.87	470	238	220	240
	0.21	0.16	0.14	0.18	-	-	-	-
Phosphates	0.22	0.90	0.20	0.77	649	221	237	238
	0.02	0.08	0.08	0.09	0.15	1.36	0.00	4.20
Potassium	6.20	2.40	5.20	2.65	344	8	84	192
	1.84	1.76	1.94	1.14	-	-	-	-
Coli titre	10.00	10.00	5.00	4.00	459	217	120	140
	6.98	3.41	0.77	1.06	8.06	39.63	75.00	59.29

- not determined

Quality of water in the Myczkowce reservoir during 1971-1990

Indicator	Max (g/m <sup>3</sup> )				Number of analyses			
	Average (g/m <sup>3</sup> )				Percentage of values higher than those for 1st class			
	Time				Time			
	1971-1975	1976-1980	1981-1985	1986-1990	1971-1975	1976-1980	1981-1985	1986-1990
Colour, Pt	25.00	25.00	20.00	25.00	88	57	59	75
	10.50	11.52	10.56	15.67	6.82	14.03	5.08	41.33
Smell	2.00	5.00	5.00	5.00	43	57	63	75
	1.05	2.00	2.67	2.13	0.00	7.02	7.94	8.00
Turbidity	35.00	50.00	15.00	20.00	86	57	59	105
	8.99	9.65	6.13	5.94	-	-	-	-
Suspended solids	42.00	16.00	12.40	16.30	88	16	53	75
	10.05	9.03	3.73	3.27	10.23	0.00	0.00	0.00
pH	8.43	8.40	8.40	8.55	109	57	63	75
	7.90	7.85	7.95	7.93	33.03	8.77	31.75	53.33
Calcium	48.50	48.88	68.60	56.14	37	16	63	74
	38.23	36.74	37.32	33.54	-	-	-	-
Iron	0.39	0.30	0.54	0.50	86	57	47	75
	0.09	0.11	0.11	0.16	0.00	0.00	0.00	0.00
Magnesium	17.15	20.90	25.27	21.41	37	16	63	74
	5.62	10.85	11.89	10.36	-	-	-	-
Sulphates	27.00	49.70	99.70	53.08	88	57	60	75
	17.25	30.82	33.05	29.60	0.00	0.00	0.00	0.00
Chlorides	14.20	16.90	27.00	15.00	88	53	61	75
	7.94	9.50	8.41	7.87	0.00	0.00	0.00	0.00
Dissolved oxygen	12.80	13.00	12.30	11.00	109	57	59	75
	9.73	9.24	9.90	8.60	0.00	1.75	0.00	4.00
BOD	3.30	4.10	3.07	13.00	110	57	59	75
	1.78	1.81	1.50	1.73	0.00	1.75	0.00	1.33

Oxygen consumption	10.50	8.00	6.20	7.05	88	53	37	75
	2.80	3.26	2.87	3.02	1.14	0.00	0.00	0.00
Ammonia nitrogen	0.320	0.220	0.370	0.594	88	53	41	74
	0.039	0.054	0.099	0.136	0.00	0.00	0.00	0.00
Nitrates	3.000	2.470	2.450	5.396	87	57	63	75
	1.116	0.686	1.007	1.495	28.74	8.77	14.29	40.0
Nitrogen	0.100	0.070	0.080	0.140	88	57	63	75
	0.015	0.009	0.010	0.009	-	-	-	-
Organic nitrogen	1.940	1.500	2.160	2.896	88	53	41	74
	0.602	0.676	0.857	1.271	17.04	5.66	24.39	56.76
Total phosphorus	0.55	1.60	0.50	0.65	69	57	59	74
	0.11	0.18	0.14	0.15	-	-	-	-
Phosphates	0.15	0.19	0.50	0.23	75	45	63	74
	0.03	0.08	0.11	0.08	0.00	0.00	4.76	2.70
Potassium	5.80	1.80	2.30	2.58	46	4	20	69
	2.33	1.60	1.65	1.09	-	-	-	-
Coli titre	10.00	10.00	4.00	2.00	42	55	30	48
	3.65	1.51	0.30	0.47	14.29	60.00	93.33	87.50

- not determined

Sampling points in the Solina and Myczkowce reservoirs  
representing the lowest percentage of values higher than those characteristic of water of first class purity in 1971-1990

Indicator	Five-year period	Sampling point								
		A/S	B/S	C/S	D/S	E/S	F/S	A/M	B/M	C/M
Dissolved oxygen	1	2.5	2.1	1.7	1.6	1.9	0.0	0.0	0.0	0.0
	2	11.4	0.0	6.8	9.5	2.5	0.0	0.0	3.4	-
	3	0.0	0.0	0.0	9.4	9.4	0.0	0.0	0.0	0.0
	4	20.0	10.0	10.0	7.5	15.0	12.5	6.7	3.3	0.0
BOD	1	0.0	0.0	1.7	0.0	0.0	0.8	0.0	0.0	0.0
	2	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	-
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7
Oxygen consumption	1	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	2.1
	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Suspended solids	1	11.3	10.4	18.4	12.3	4.1	9.0	0.0	0.0	19.1
	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Colour	1	14.3	8.8	22.9	4.8	11.7	2.7	10.5	9.1	4.3
	2	6.8	2.4	2.3	0.0	0.0	0.0	17.9	10.3	-
	3	2.8	2.8	2.8	0.0	0.0	5.6	7.1	0.0	33.3
	4	55.0	50.0	30.0	35.0	42.5	53.3	40.0	46.7	33.3
pH	1	40.5	45.0	44.4	12.3	30.8	14.9	11.5	2.8	68.1
	2	29.5	23.8	27.3	23.3	15.0	38.1	3.6	13.8	-
	3	52.5	35.0	32.5	35.0	37.5	40.0	30.0	30.0	66.7
	4	50.0	55.0	27.5	52.0	45.0	40.0	56.7	56.7	40.0
Coli titre	1	9.3	3.6	17.7	5.4	4.4	1.8	33.3	0.0	20.0
	2	45.9	33.3	40.5	33.3	42.1	42.4	64.3	55.6	-



	3	75.0	70.0	80.0	85.0	55.0	85.0	85.7	100	100
	4	43.3	45.4	59.1	68.2	59.1	86.4	83.3	90.0	90.0
Nitrates	1	20.2	25.2	41.7	49.5	19.6	40.6	52.6	45.4	10.9
	2	0.0	11.9	15.9	18.6	20.0	19.0	7.1	10.3	—
	3	5.0	10.0	7.5	12.5	3.7	12.5	13.3	13.3	33.3
	4	32.5	42.5	35.0	37.5	37.5	25.0	33.3	43.3	46.7
Organic nitrogen	1	22.2	17.5	31.7	15.8	20.4	14.2	21.0	18.2	14.9
	2	7.1	0.0	4.8	0.0	7.9	7.1	7.7	3.7	—
	3	22.5	22.5	30.0	27.5	15.0	32.5	20.0	22.2	66.7
	4	72.5	70.0	57.5	77.5	67.5	67.5	53.3	55.2	66.7
Iron	1	0.0	0.0	0.7	0.6	0.0	0.0	0.0	0.0	0.0
	2	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0
	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphates	1	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0
	2	2.8	0.0	0.0	5.4	0.0	0.0	0.0	0.0	—
	3	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
	4	7.5	0.0	10.0	2.5	5.0	0.0	0.0	3.4	6.7
Average % of transgressions of 1st class	1	10.9	10.2	16.5	9.4	8.4	8.7	11.7	6.9	12.7
	2	9.4	6.5	9.1	8.2	7.9	9.8	9.5	8.8	—
	3	14.3	12.7	13.9	15.4	11.0	16.0	15.1	15.0	27.3
	4	25.7	24.8	21.1	25.5	24.7	24.7	24.8	27.1	26.4
Sequene	1	5	4	6	3	1	2	2	1	3
	2	5	1	4	3	2	6	2	1	—
	3	4	2	3	5	1	6	2	1	3
	4	6	4	1	5	2	3	1	2	3
	1-4	6	2	3	4	1	5	2	1	3

— no data

Such an improvement was probably related to the termination of the transformation of impurities at the bottom of the reservoir before it was flooded. However, there was a simultaneous increase in the concentration of phosphates, turbidity, iron, magnesium, calcium, chlorides and sulfates, and, what should be emphasized, an increase in the bacterial impurities and a decrease in the amount of oxygen dissolved in water.

During the same period, in the reservoir at Myczkowce there was observed an increase in the colour intensity, turbidity, BOD, oxygen consumption, concentrations of organic nitrogen, phosphorus, sodium, phosphates, magnesium, iron, chlorides, sulfates and bacterial impurities. Simultaneously the concentration of nitrates and the content of oxygen dissolved in water decreased. It was found that the values of water quality indicators varied at different sampling sites.

The indicators whose values exceeded those permissible for the first-class water purity [9], enlisted in table 3, provide evidence of the changes during four successive five-year periods at 11 sites.

On the basis of the lowest mean percentage characteristic of indicators which exceeded the 1st class water purity standards, the sampling sites of the "purest" water were arranged in sequence. From comparison of the data it follows first of all that in the Solina reservoir an increase in the percentages of bacterial impurity was the cause of the change of the F/S sampling site position from the second to the last. This was probably the result of putting into operation the sewage-treatment plant in Polańczyk at the end of 1971, a double increase in the amount of the sewage disposed in the other periods compared with the first one as well as no disinfection of the treated sewage water discharged into the Solina reservoir [9].

It was the E/S sampling point at Solina, upstream from the dam, that turned out to be stable as regards the quality of water, during the whole twenty-year period. Nearby, a water intake for the group water line is located which supplies water to the timber plant at Ustianowa, the town of Ustrzyki Dolne as well as to the nearby villages [10].

Within the twenty years there were no changes in the positions of the sampling sites at the Myczkowce reservoir. In spite of an increase in the percentage of the values exceeding the permissible indicators (colour, smell, pH and *E. coli* titre), the "purest" water was still found in the E/S sampling site upstream from the dam.

#### 4. CONCLUSIONS

1. In 1971–1990, deterioration of water quality in the Solina and Myczkowce dam reservoirs took place.
2. The sanitary conditions of both reservoirs deteriorated considerably which is evidenced by a relatively high percentage of the values exceeding the permissible value of the *E. coli* indicator characteristic of the first-class purity of water.

### 3. The causes of the deterioration in water quality were:

- insufficiently treated sewage water from the mechanical-biological sewage-treatment plant at Polańczyk,
- local impurities from unreasonably managed direct basins and river basins of both reservoirs,
- intensive development of tourism and related infrastructure,
- sheep breeding and pasturing.

4. The investigation of the water quality of both dam reservoirs proved that the existing sewage-treatment plants should be adapted for removal of biogenic compounds to protect the water resources from eutrophication.

5. Water in dam reservoirs is protected from the inflow of biogenic compounds in result of operation of drainage system which disposes polluted water below the reservoirs.

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#### ZMIANY JAKOŚCI WÓD ZBIORNIKÓW SOLINA-MYCZKOWCE W LATACH 1971–1990

Celem pracy było określenie zmian jakości wód zbiorników Solina-Myczkowce na podstawie wyników badań fizyczno-chemicznych. Stwierdzono, że w okresie 1971–1990 jakość wody pogorszyła się. Nastąpił wzrost zanieczyszczeń bakteriologicznych oraz stężeń fosforanów, żelaza, magnezu, wapnia, chlorków i siarczanów. Zwiększyła się intensywność zabarwienia i mętność wody. Na stanowisku E/S powyżej zapory w Solinie jakość wody była stabilna.

## ИЗМЕНЕНИЯ КАЧЕСТВА ВОДЫ СОЛИНСКОГО И МЫЧКОВСКОГО БАСЕЙНОВ В ПЕРИОД 1971–1990

Целью работы было определение изменений качества воды солинского и мычковского бассейнов. На основе результатов физико–химических исследований отмечено, что в период с 1971 по 1990 год наступило ухудшение качества воды солинского и мычковского бассейнов. Наступил рост бактериологических загрязнений, а также концентраций солей фосфорной кислоты, железа, магния, кальция, хлоридов и сульфатов. Повысилась интенсивность окраски и мутности воды. На стенде Е/С выше плотины в Солине качество воды было стабильным.