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SELECTED QUALITY INDICTATORS FOR WATER DRAWN FROM A RETENTION RESERVOIR

The quality raw water drawn from a waterworks retention reservoir was assessed. Water was drawn by the tower intake from three different levels. In order to characterize the extent of eutrofication, the concentrations of phosphates, dissolved oxygen, and chlorophyll *a* were determined. The water quality coefficients unequivocally showed that water drawn from the reservoir is appropriate for waterworks' purposes. Our one reservation concerned a higher level of chlorophyll *a*, being characteristic of an algal bloom and a symptom of eutrofication. Level II has been ascertained to be the most suitable as the source for the waterworks (metalimnion).

1. INTRODUCTION

Groundwater is often used to supply drinking water of high quality, although considering its limited availability surface waters are increasingly being used. This is the source of potable water for the majority of Polish waterworks. In the case of direct drawing from rivers, treatment processes must be flexible enough to handle variable river quality while fulfilling the requirements for potable water. For this reason, water providers choose to draw water from retention reservoirs, which act to stabilize water quality and allow the storage of water supplies. A drawback of reservoirs is that a variety of processes occur. They link the management of the reservoir with the management of the catchment. One of the main factors deteriorating the reservoir water quality is eutrofication.

2. RESEARCH PROCEDURES

The aim of this research was to evaluate raw water quality drawn from a barrier reservoir for waterworks purposes. Water was drawn by the tower intake from three

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different levels. Three coefficients characterizing eutrofication were analyzed: the concentration of phosphates, dissolved oxygen and chlorophyll *a*. The observation period lasted for 3 years, from January 2003 to December 2005.

The research was carried out on Dobczyce Lake, a man-made retention reservoir having a total volume of 125 mln m^3 and serving as the main source of potable water for Kraków. The "Raba" Water Treatment Plant (WTP) in Dobczyce supplies about 100 thous. m^3 daily.

Three bodies of water can be distinguished in Dobczyce Lake: Dobczyce Basin characterized by complete biannual mixing; Myślenice Basin and Wolnica Bay which have continuous mixing only excluding the period with ice cover. For inflow, the tower intake draws water from three different levels: level I – 3.55 m depth in the epilimnion layer, level II – 9.65 m in the metalimnion layer and level III – 15.87 m in the hypolimnion layer.

A real threat to water clarity in the reservoir comes from contaminants introduced by the following direct inflows: the Raba River, Bulinka and Trzemeśnianka streams, surface flows from the reservoir catchment, as well as eutrofication processes which occur in the reservoir itself. According to Voivodeship Inspectorate for Environmental Protection in Kraków, a general evaluation in terms of purity classes for the above mentioned inflows is not possible due to poor sanitary conditions caused by household sewage inflow as determined from a bacteriological evaluation. Physicochemical coefficients and the results from the hydrobiological evaluation in the above mentioned streams correspond to A1 and A2 purity classes. In the Raba River, periodic overstepping of ratios characteristic of pure waters occurs relating mainly to ammonium and nitrogenous nitrogen, total phosphorus, manganese, detergents, and the coli titre of faecal type. Computed loads of nitrogen and phosphorus brought into the reservoir by the Raba River with average volumes of water flow (10.6 $m^3 \cdot s^{-1}$) were 50 t N_{tot} and 33 t P_{total}, respectively, per year [1].

The data presented shows that the basic problem is the inflow of contaminants mainly from municipal sources [2]. Several towns in the Raba catchment lack any efficient wastewater treatment system. Manure from farms is generally used for agricultural purposes; however, it often reaches the groundwater. The threat is multiplied by the soil profile in the reservoir catchment which consists of clayey soils with a rather scarce skeleton in the upper layer. These soils have a relatively small permeability and retention and thus promote large surface flow and soil erosion.

Water samples were collected once a week from three levels (I, II, III) using special pumps placed in front of inlet windows of the tower intake. This sampling method ensured the averaging of samples due to good mixing in each inlet zone window.

The water quality coefficients were determined in the WTP "Raba" in Dobczyce laboratories. Phosphorus was evaluated with a Hach DR 4000 spectrophotometer. The dissolved oxygen concentration was found using the microprocessor oxygen meter Oxi 538. The amount of chlorophyll *a* was determined using the monochromatic spectrophotometer method, with correction for feopigments, with a Hach DR 4000 spectrophotometer [3].

3. RESULTS AND DISCUSSION

Dissolved oxygen in water originates from atmospheric exchange and from primary production. Water oxygenation is one of the basic factors determining the location of water organisms. In the epilimnion (level I), organic synthesis and oxygen production occur due to photosynthesis, exceeding organic substance decomposition and the oxygen demand. In hypolimnion (level III), organic matter produced in the epilimnion is decomposed, resulting in a high oxygen demand. Following the spring bloom, oxygen depletion in level III (hypolimnion) may be observed. The next time the oxygenation of water occurs is during the autumn circulation (figure 1).

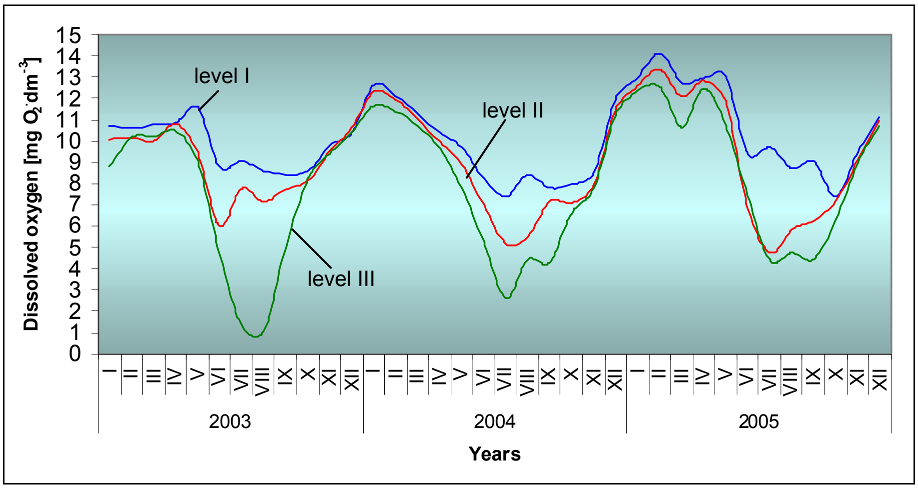

Fig. 1. Average monthly oxygen concentration dissolved in raw water from three levels in 2003–2005

Phosphates in surface water come from material dissolution, soil erosion, sewage inflow, surface flows, and atmospheric precipitation. The phosphate concentration in the reservoir changes periodically. In the epilimnion, during the summer stagnation period, phosphate concentration decreases as a result of its assimilation by developing phytoplankton. After phytoplankton decay and decomposition, phosphorus is partially released into deep water. Its remaining part sediments and is deposited in bottom sediment, from which it is released into hypolimnion under conditions of oxygen deficiency. The phosphate concentration increases from late autumn until early spring when primary production is low (figure 2). This cycle, however, may be disturbed by the inflow of sewage with a high phosphorus concentration.

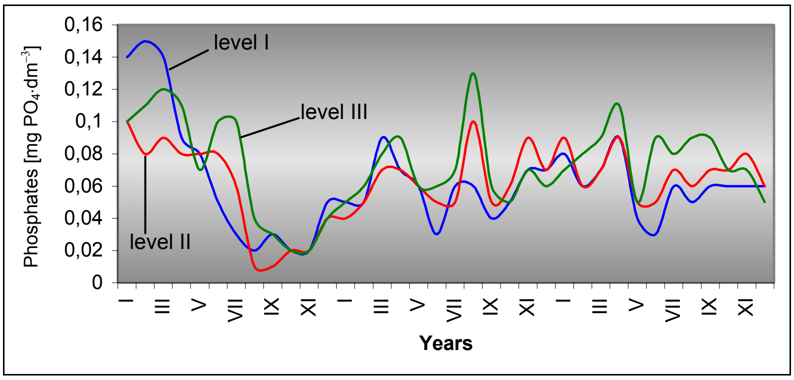

Fig. 2. Average monthly phosphate concentration dissolved
in raw water from three levels in 2003–2005

Presently, the applicable legal regulations on using surface water for supplying potable water do not require the chlorophyll *a* determination [4]. Nonetheless, since surface water is rich in biogenic substances, which promote mass development of phytoplankton, this coefficient has also been evaluated (figure 3). Mass development of phytoplankton may lower water quality and in some cases may exclude it from being used as a source [5]. The concentration of chlorophyll *a* is the plankton algae biomass index.

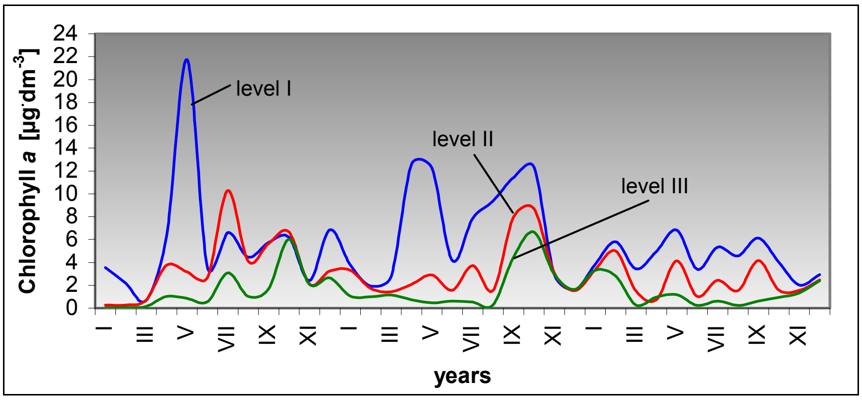

Fig. 3. Average monthly amount of chlorophyll *a*
in raw water from three levels in 2003–2005

Data from literature shows that the amount of chlorophyll *a* up to 10 µg·dm^{-3} is treated as neutral for surface waters. Higher concentrations indicate excessive phytoplankton development. The concentrations above 30 µg·dm^{-3} indicate mass development of these organisms (algal bloom) and in most cases this disqualifies the water as a source for waterworks supply.

From the 3-year observation period, the water layer drawn from level I was determined to have a high concentration of planktonic algae, which inhibits water treatment. During the algal bloom period, water from level I should not be drawn, especially due to toxin-producing cyanobacteria; although this level is distinguished by having the highest concentration of dissolved oxygen.

Water from level II is characterized by relatively low production and low decay. This translates into a lower concentration of algae compared to level I. Phytoplankton may occur only periodically in increased amounts during a bloom. At the end of summer, the water has a low dissolved oxygen concentration. According to hydrobiologists studying the reservoir, the drawing of water from this level for waterworks purposes is likely the most advisable [6].

Water drawn from level III contains the lowest algal concentration, but it may be of poor quality due to a low oxygen concentration.

Table

Comparison of minimal, maximal and mean raw water quality coefficients in Dobczyce Lake in 2003–2005

Level of water intake	Ratio	Unit	Years								
			2003			2004			2005		
			min	max	mean	min	max	mean	min	max	mean
I	dissolved oxygen	mg $O_2 \cdot dm^{-3}$	7.8	13.8	9.9	6.7	12.7	9.7	6.6	18.4	10.9
	phosphates	mg $PO_4 \cdot dm^{-3}$	0.00	0.23	0.07	0.02	0.12	0.06	0.02	0.12	0.06
	chlorophyll *a*	$\mu g \cdot dm^{-3}$	0.15	31.79	5.86	0.62	24.94	6.92	0.58	13.55	4.43
II	dissolved oxygen	mg $O_2 \cdot dm^{-3}$	5.2	11.9	9.0	4.1	12.7	8.8	3.9	16.1	9.5
	phosphates	mg $PO_4 \cdot dm^{-3}$	0.00	0.14	0.06	0.03	0.17	0.06	0.03	0.12	0.07
	chlorophyll *a*	$\mu g \cdot dm^{-3}$	0.06	15.67	3.57	0.26	12.63	3.30	0.09	7.69	2.46
III	dissolved oxygen	mg $O_2 \cdot dm^{-3}$	0.6	11.8	7.4	2.0	12.4	7.8	2.5	14.5	8.8
	phosphates	mg $PO_4 \cdot dm^{-3}$	0.01	0.16	0.07	0.03	0.19	0.07	0.03	0.15	0.08
	chlorophyll *a*	$\mu g \cdot dm^{-3}$	0.00	8.18	1.60	0.07	9.18	1.79	0.00	5.09	1.24

The water quality coefficients under analysis show that water drawn from Dobczyce Lake is suitable for waterworks purposes (table) [4]. The water quality indicates that the reservoir is only slightly polluted; however, the most pressing problem is the increased chlorophyll *a* concentration, reaching the values characteristic of algal bloom. This is also a symptom of eutrofication, which may cause negative changes in the reservoir ecosystem and deteriorate the quality of drawn water.

4. CONCLUSIONS

The analysis presented proves that controlling the level of water being drawn is advisable to ensure the highest quality possible. This was shown by the parameters determined:

1. The lowest dissolved oxygen concentration occurs in level III (0.6 mg $O_2\cdot dm^{-3}$), and the highest in level I (18.4 mg $O_2\cdot dm^{-3}$).
2. The water is characterized by a low phosphate concentration (up to 0.23 mg $PO_4\cdot dm^{-3}$) which does not significantly vary with level.
3. Chlorophyll *a* reaches the highest concentration in level I during the algal bloom period (up to about 32 $\mu g\cdot dm^{-3}$). This periodically disqualifies water drawn from this level as a waterworks source.
4. The 3-year study shows a slight improvement in water quality for the parameters analyzed in all three levels. The exception to this is the phosphate concentration in levels II and III.
5. Taking into account the water quality coefficients analyzed, level II (metalimnion) is the most advisable level for drawing source water to be used in waterworks.

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KSZTAŁTOWANIE WYBRANYCH WSKAŹNIKÓW JAKOŚCI WODY UJMOWANEJ ZE ZBIORNIKA ZAPOROWEGO

Dokonano oceny jakości wody surowej ujmowanej ze zbiornika zaporowego do celów wodociągowych. Wodę pobierano przez ujęcie wieżowe z trzech poziomów czerpania. Analizie poddano wartość trzech wskaźników charakteryzujących proces eutrofizacji. Były to: fosforany, tlen rozpuszczony oraz

chlorofil *a*. Analizowane wskaźniki jakości wody jednoznacznie wykazały, że woda ujmowana ze zbiornika jest odpowiednia do celów wodociągowych. Zastrzeżenia budzi jedynie podwyższona zawartość chlorofilu *a* osiągająca wartości charakterystyczne dla zakwitu glonów, co jest objawem procesu eutrofizacji. Stwierdzono, że najkorzystniejszym poziomem poboru wody do celów wodociągowych jest poziom II (metalimnion).