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ScienceDirect
APCBEE Procedia 10 (2014) 26 – 30
Procedia APCBEE
www.elsevier.com/locate/procedia

ICESD 2014: February 19-21, Singapore

Innovative Solutions in Surface Water Quality Monitoring

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Abstract

In 2010 a project entitled "Integrated Support System for Management and Protection of Water Dam Reservoir (ZiZOZap)" was initiated, to aid solving water management problems on a river and dam reservoir formed on it. An innovative system of continuous monitoring was created, that encompassed selected physical and chemical parameters of river and lake waters in three chosen sites. This article presents a selection of results, that were obtained thanks to the continuous monitoring. In particular, monitoring of parameters with high diurnal variability benefits from this measurement design. Sites that are essential for water management are recommended to be monitored in this way.

Selection and peer review under responsibility of Asia-Pacific Chemical, Biological & Environmental Engineering Society

Keywords: water management, water quality monitoring, water dam reservoir

1. Introduction

One of contemporary problems of water management is the deterioration of ecological and functional potential of lakes, rivers and reservoirs as a result of catchment area management. At the same time there are expectations to increase this potential which makes it necessary to carry out strict monitoring of water quality.

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Selection and peer review under responsibility of Asia-Pacific Chemical, Biological & Environmental Engineering Society
doi:10.1016/j.apcbee.2014.10.009

In 2010 a project 'Integrated Support System for Management and Protection of Water Dam Reservoir (ZiZOZap)' was initiated, which led to creation of an innovative system of continuous monitoring of chosen physical and chemical parameters. The advantages and disadvantages of a continuous monitoring approach are still under debate [1], [2], and in the studies based on infrequent observations the problem of possible artifacts from that strategy are mentioned [3]. Here, we present both design and data from an existing continuous monitoring programme, to highlight the practical outcomes of this approach.

2. Study area. Materials and methods

The subject of research is the 'Goczałkowice' reservoir damming the waters of the Vistula river. The reservoir was built in 1950-1955 in the Upper Vistula valley, mainly to supply water to a nearby industrial conurbation, inhabited by over 3 million people. The 'Goczałkowice' reservoir has multiple functions, except drinking water storage these are: flood control, compensation of low-flow, fisheries management, environmental protection and recreation [4].

The location of monitoring sites was chosen as a result of field research, bathymetric chart analysis, and historical and contemporary data review on changes of the Vistula's discharge). This guaranteed that the tested sites were representative for the parameters measured. Eventually three research sites were chosen (Fig. 1).

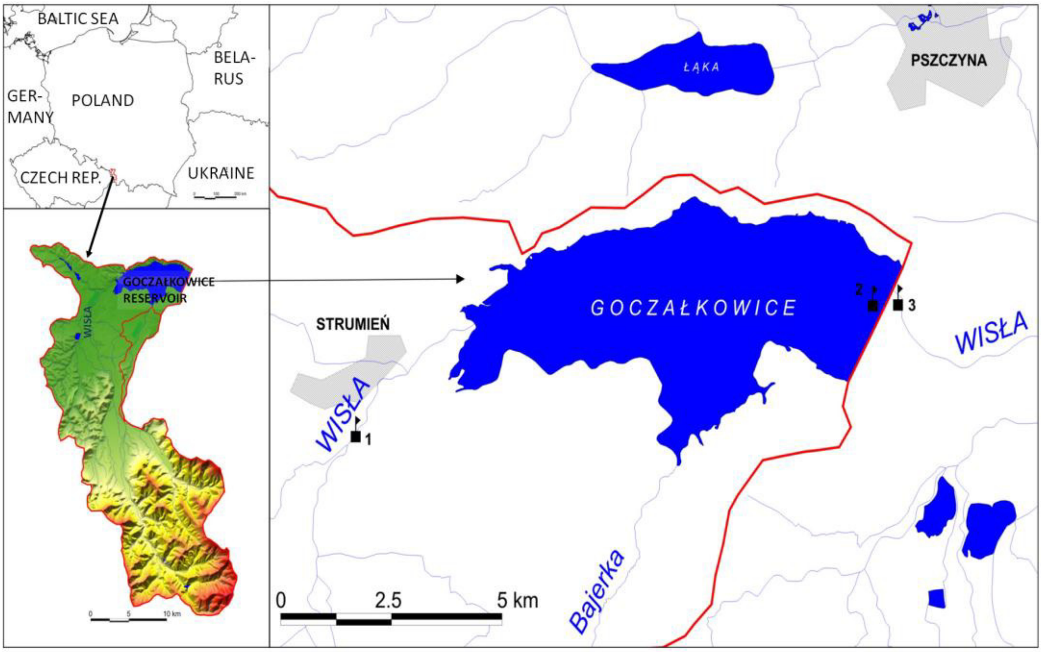

Fig. 1. Location of monitoring sites: 1 - The Vistula - weir in Strumień – inflow to the reservoir; 2 - Pelagic zone of the reservoir in its deepest point, in the old Vistula riverbed – about 400 m southwest of the bottom outlet of the dam; 3 - The Vistula – outflow from the reservoir.

Continuous monitoring of physical and chemical properties of water is performed with multi-parameter probes DS5X by OTT Messtechnik GmbH, that measure the following parameters: water temperature, dissolved oxygen, pH, redox potential, specific electric conductivity, chlorophyll, turbidity, as well as ammonia, nitrate and chloride content. The probes have a self-cleaning system that removes dirt from the electrodes before each measurement, which guarantees maximum reliability of tests. The probes can test 15 parameters at the same time. Results are collected in the probe's memory and their interval may be programmed at one's discretion.

The probe on the reservoir was mounted on a buoy which additionally makes basic meteorological measurements. It also has an autonomous power supply system based on solar panels. Data transmission from the whole system is done remotely through GSM-GPRS modems. This makes it possible to immediately access the gathered measurements and remotely configure selected parameters.

3. Results

Monitoring of the 'Goczałkowice' reservoir carried out since 2010 provides important information about the quality of waters flowing into and out of the reservoir. It makes it possible to assess the impact of the reservoir on water quality and provides meteorological information. All tested parameters contribute to the model of the reservoir's functioning. The scope of selected parameters is the resultant of technical measurement possibilities and legal requirements. The obtained results have been summarised for the period from June 2010 to January 2013 in Table 1.

Table 1. Mean, minimum and maximum values of selected physical and chemical parameters of water in all three monitoring sites in the period from June 2010 to January 2013.

Parameter	Conductivity	pH	Water temperature	Dissolved oxygen	Turbidity	Chlorides	Nitrate nitrogen	ORP Redox
Unit	$\mu S\ cm^{-1}$	-	°C	$mg\ O_2\ dm^{-3}$	NTU	$mg\ Cl\ dm^{-3}$	$mg\ N\text{-}NO_3\ dm^{-3}$	mV
Mean value	196.6	7.6	10.9	8.3	99.5	35.6	1.8	390.5
Minimum value	101	6.03	0.03	0.71	0	1	0.03	-91
Maximum value	357	9.9	90.25	27.04	3000	181	23.96	1000

In the light of Polish law regulations the presented mean values should be categorised as class I water quality (very good state/potential) with the exception of nitrate nitrogen falling into class II (good state/potential).

All presented mean values for reservoir water should be classified as class I (very good state/potential) according to legal regulations. However, high values of oxygen content in the waters of the lake are interesting. In the summer period the waters of the reservoir in epilimnion reach the state described as supersaturation (up to 17.65 mg O_2 dm^{-3}, which is a level similar to that found in the cold waters of Antarctic lakes [5]). This is caused by massive production of oxygen by growing phytoplankton. Besides oxygen, CO_2 is also present in lake water, which significantly influences the pH values. Growing algae take significant amounts of CO_2, at the same time causing the increase of water reaction (pH). In the reservoir there is a gradual increase in this parameter, starting from values near 7 in the winter period up to maximum values in the summer period (pH = 9.9). Such high pH values provide conditions for the biomass to grow, what is indicated by high concentrations of chlorophyll in the waters of the lake in August 2010 (90.25 µg dm^{-3}).

Water eutrophication is the greatest threat for the reservoir despite the fact that in the light of the carried out research the ecological potential for the reservoir has been defined as good and above good. The role of the catchment of the reservoir in shaping quality parameters and impact of the surroundings on reservoir degradation expressed as Schindler's index (category II) makes the reservoir moderately susceptible to degradation. The value of the index suggests that the catchment plays an insignificant role in shaping the quality of the reservoir's water.

An important innovation of continuous monitoring is the possibility of observing continuous changes in water temperature in the reservoir (Fig. 2). In 2010 it was proven that in the reservoir there is thermal stratification despite relatively small maximum depth of the reservoir. Maximum water temperature in the vertical profile shows differences exceeding 11ºC (Fig. 2). At the end of August as a result of cooling surface layers of water and their wind and convection mixing, differences in temperature between epilimnion and hypolimnion disappear. Cooling finishes with reaching the temperature of 4ºC in the whole thermal profile (autumn homothermia), which in the described reservoir happens at the end of November/beginning of December.

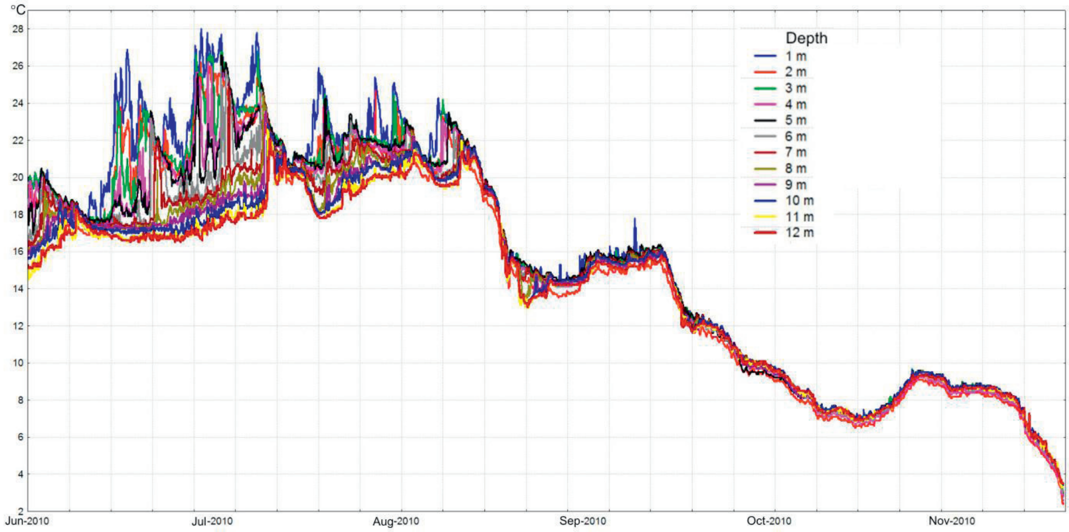

Fig. 2. Temperature changes in vertical profile of waters in the Goczałkowice reservoir from June until December 2010

In the light of binding regulations all the presented mean values in the cross section downstream of the reservoir should fall into class I (very good state/potential).

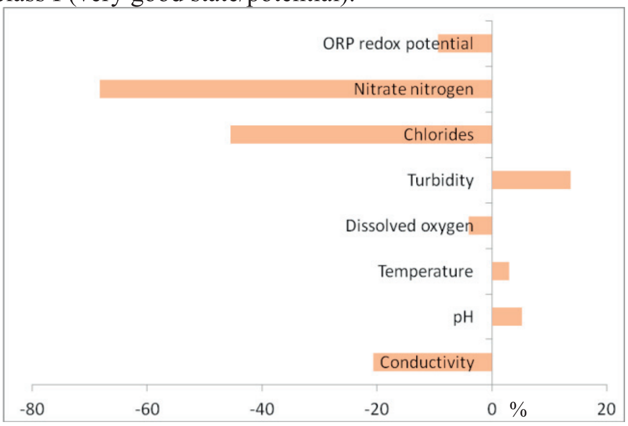

Fig. 3. The difference between selected physical and chemical parameters of waters in the Vistula flowing out of the "Goczałkowice"

reservoir and in its inflow (in the period from June 2010 till January 2013)

From the point of view of ecology each river is an open ecosystem which is in a state of dynamic equilibrium [6], [7]. Breaking the continuum of a river with a barrage influences hydrological conditions which can significantly shape physical, chemical and biological processes determining the quality of water in a reservoir, and thus the river downstream of the dam [8], [9]. Continuous research monitoring of physical and chemical parameters of water makes it possible to analyse the impact of the 'Goczałkowice' reservoir on the quality of waters in the Vistula downstream of the reservoir.

Research has shown that the reservoir exhibits significant chemical retention and most of the quality parameters improve (Fig. 3), consistent with the observation from the Huai River Basin, that in the upper reaches of rivers, the reservoirs tend to improve the water quality [10]. The pH, which slightly increases, is an exception, what is caused by eutrophication processes in the reservoir. Water temperature also increases, which is mostly connected with the area of the reservoir and retention time. There is also a slight increase in turbidity caused by outlet devices of the dam.

4. Conclusions

Measurements with the use of automatic probes providing continuous access to the results regardless of the weather, season, day or meteorological conditions are the future of monitoring water quality. The results obtained in this way are much more representative than the ones obtained in the traditional way, and allow to observe processes in more detail. Some parameters with great day to day variability such as chlorophyll concentration or dissolved oxygen reveal interesting diurnal patterns when monitored continuously. Frequent measurements improve the accuracy of mean values estimation and enhances interpretation potential in water research. Reaction to water quality related threats may be faster also, which is particularly important for the reservoir supplying water to over 3 million people.

References

[1] Bulucea C. A., Popescu M. C., Bulucea C. A., Manolea G., Patrascu A. Interest and Difficulty in Continuous Analysis of Water Quality, *Proceedings of the 4th IASME / WSEAS International Conference on ENERGY & ENVIRONMENT (EE'09)* 2009; 220-225.

[2] Cassidy R., Jordan P. Limitations of instantaneous water quality sampling in surface-water catchments: Comparison with near-continuous phosphorus time-series data, *J Hydrol* 2011; **405**: 182–193.

[3] Ellwood N. T.W., Albertano P., Galvez R., Funiciello R., Mosello R. Water chemistry and trophic evaluation of Lake Albano (Central Italy): a four year water monitoring study, *J Limnol* 2009; **68**: 288-303.

[4] Absalon D., Matysik M., Ruman M. Location, hydrological conditions and factors influencing water quality of Goczałkowice Reservoir and its catchment. *Anthropogenic and natural transformations of lakes* 2011; **5**: 7–15.

[5] Green W. J., Lyons W. B. The Saline Lakes of the McMurdo Dry Valleys, Antarctica, *Aquat Geochem* 2009; **15**: 321–348.

[6] Allan J.D. *Ekologia wód płynących (Ecology of flowing waters)*. Warszawa: PWN; 1998.

[7] Kajak Z. *Hydrobiologia - limnologia. Ekosystemy wód śródlądowych (Hydrobiology - limnology. Inland water ecosystems)*. Warszawa: PWN; 1998.

[8] Ward J.S., Stanford J.A. The intermediate - disturbance hypothesis: an explanation for biotic diversity patterns in lotic ecosystems. Dynamic of lotic ecosystems. *Publ Ann Arbor Sci* 1983; 347–356.

[9] Kajak Z. *Changes in river water quality in reservoirs, exemplified by studies in Poland. Regulated rivers.* Oslo: Universitetsforlanget AS 1984; 521–531.

[10] Zhang Y., Xia J., Liang T., Shao Q. Impact of Water Projects on River Flow Regimes and Water Quality in Huai River Basin, *Water Resour Manage* 2010; **24**: 889–908.