Bulletin No.2/15

„Analysis of factors affecting the ecological status of the Sulejow Reservoir based on continuous monitoring and integrated 3D model of the artificial lake (project MONSUL)”

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Project

MONSUL

1. INTRODUCTION

We're halfway through the project. For this reason, we publish the second issue of our bulletin describing the first results of the implementation of the MONSUL project. We will describe how we synchronised and effectively used three research platforms which monitor the status of the water as well as biological, physical and chemical parameters of the Sulejów Reservoir. We also want to show how the large amount of detailed data collected in field conditions and real time is used to make a precise map of the reservoir. We will show how we used advanced instruments and digital models (ArcGIS and GEMSS) in design works. Finally, we will shed some light on our communication with the interested organisations and communities by organising regional seminars and presenting the results of the MONSUL project at the SDEWES 2015 Conference in Dubrovnik.

We wish you a pleasant reading – more information can be found on the project's website:

www.monsul.wipos.p.lodz.pl

MONSUL Project Team

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2. Monitoring of the water quality in the Sulejów Reservoir

In the spring of 2015, we have started the implementation of one of the most important objectives of the MONSUL project – monitoring the quality of water in the Sulejów Reservoir. The programme of this monitoring is implemented based on three interconnected research platforms:

- measurement system consisting of two probes installed on buoys anchored in the northern and central parts of the reservoir monitoring (continuously) selected water quality parameters,
- moving (floating) measurement system, based on the EXO2 probe made by YSI,
- laboratory testing – analysis of water samples collected from different points in the Sulejów Reservoir.

The first of these measurement system uses two EXO probes installed on buoys anchored in two critical points of the Sulejów Reservoir. The location of these two buoys is depicted in photograph 1.

photo no. 1

The probes installed on buoys provide continuous, automatic measurements of the following parameters of the water: temperature, pH, dissolved oxygen concentration, conductivity, chlorophyll concentration, algae concentration, ammonium ion concentration. The probes are submerged at the depth of 1.5–2.5 m under the water surface. Buoy no. 1 provided by Faculty of Process and Environmental Engineering of the Lodz University of Technology is also equipped with the meteorological sensor measuring air humidity and temperature, wind speed and direction, atmospheric pressure and insolation (photograph no. 2).

photo no. 2

The probe provided by the Norwegian Institute for Water Research (NIVA, Oslo) was located near Zarzęcin, in the central part of the Sulejów Reservoir (photograph no. 3).

photo no. 3

The data retrieved from the measurement probes are transmitted to dedicated servers and published on the MONSUL project website (www.monsul.wipos.p.lodz.pl). We invite everyone to visit our website and follow the real time measurements which show the Sulejów Reservoir water quality parameters.

The moving measurement system comprises the EXO2 probe and a GPS module for determining the probe position during measurement (photograph no. 4). The system is installed on a motorboat which can travel through the specified route on the lake in approx. 8 hours, measuring water parameters, such as: temperature, pH, dissolved oxygen concentration, conductivity, chlorophyll concentration, algae concentration, ammonium ion concentration.

photo no. 4

photo no. 4

The probe, towed by the boat is submerged to the depth of 1.5 m below the surface and the boat travels at approx. 6–7 km/h. The speed was adjusted to minimise the errors due to the inertia of the measurement sensors. The measurement data are collected in the memory cache of the datalogger and transmitted to a PC computer.

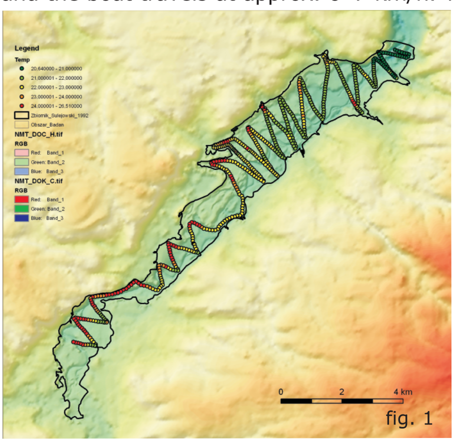

fig. 1

Using this system enables the collection of water quality data in 650–700 points located across the entire lake in one day. The measurements were performed every two weeks, from May to the end of October 2015. Figure 1 presents an example of the motorboat and probe route and water temperature measurements on 3 August 2015.

The third system involves the analysis of water samples collected from the Sulejów Reservoir. Approximately 30 water samples are collected in selected points across the reservoir along the boat route. Water samples were collected every two weeks. The following parameters were specified in the water samples from the reservoir: Chemical Oxygen Demand – COD (in the concentration range of 15 – 150 mg O_2/dm^3), Biological Oxygen Demand – BOD_5 (0.2 – 12 mg O_2/dm^3), Total Organic Carbon – TOC (2 – 65 mg C/dm^3), nitrate nitrogen (0.01 – 0.5 mg $N\text{-}NO_3/dm^3$), phosphates (0.02 – 2.5 mg PO_4^{3-}/dm^3).

The methodology of water sample determination applied in the project is compliant with the standards used in surface water monitoring studies.

The water quality parameters are measured using spectrophotometric methods, test provided by Hach-Lange. COD is determined using the dichromate method in the presence of silver sulphate as catalyst. This method is compliant with the ISO 6060-1989 standard. BOD_5 determination involves measuring the dissolved oxygen concentration in the sample on the day of collection and after 5 days of sample incubation in the stable temp. of 20C. This method of BOD_5 determination is compliant with the EN 1899-1 standard. TOC in the samples is determined by the mineralisation of organic compounds in the temp. of 100C for 2 hours. In these conditions, the organic compounds are oxidised to CO_2, which can be determined photometrically. The TOC determination method is compliant with the DIN 38409-H3 standard. Nitrate nitrogen $N\text{-}NO_3^-$ is determined by using sulphanilic acid and chromotropic acid. The coloured product of the analytical reactions is measured using the spectrophotometric method. PO_4^{3-} phosphates are determined using the reaction of these ions with potassium molybdate in an acidic environment. This method is compliant with the PN-EN ISO 6878-2006 standard.

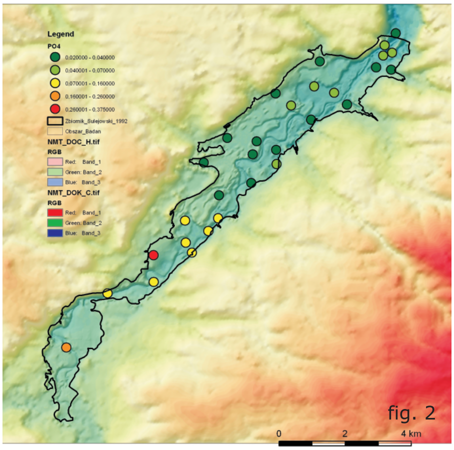

fig. 2

Each of the determinations performed within the scope of the discussed tests was made twice and the final results are the mean value of the two measurements. Within the scope of the studies related to the implementation of the project, the concentrations of TOC, N-NO_3^-, PO_4^{3-}, COD, BOD_5 were determined for over 200 water samples collected from the Sulejów Reservoir in the period from April to September 2015. Fig. 2 shows the examples of phosphate ions concentration measurements (in mg PO_4^{3-}/dm^3) for 10.06.2015, in different parts of the Sulejów Reservoir.

In conclusion, the comprehensiveness and broad range of monitoring implemented within the MONSUL project should be mentioned. The test results obtained in the course of implementation of the three interconnected measurement programmes enable a comprehensive assessments of the ecological status of the water in the Sulejów Reservoir. They also enable the tracking of the pace of changes in the parameters in time and space. The results of monitoring measurement will be also used to develop and modify the mathematical model of the Sulejów Reservoir which will enable the modelling of its ecological status.

3. Data from the deck straight to the digital map of the reservoir

The development of the Geographical Information Systems (GIS) made the creation of maps depicting the spatial distribution of a quality parameter in the geographic environment quicker and easier to interpret. The maps developed using the system serve scientific, popularisation and information purposes. The MONSUL project involved 12 all-day cruises with a motorboat. During the cruise, the submerged probe collected water parameters data. Due to the installed GPS system, the data could be spatially developed. Raw data were processed and adapted to the GIS database format. After uploading to the ArcGIS software by ESRI, the data were placed spatially and each measurement could be visualised as a measurement point on the surface of the lake. After displaying the data against the previously prepared digital maps of the Sulejów Reservoir, we received the image of all measurement points. By assigning measurement data to each of the points, we received the distribution of the water parameters along the boat route (fig. 3). From each of the cruises, we received 6 maps with measurement points – after 12 cruised we were able to put together 72 maps depicting the spatial distribution of the parameter on the day of measurement.

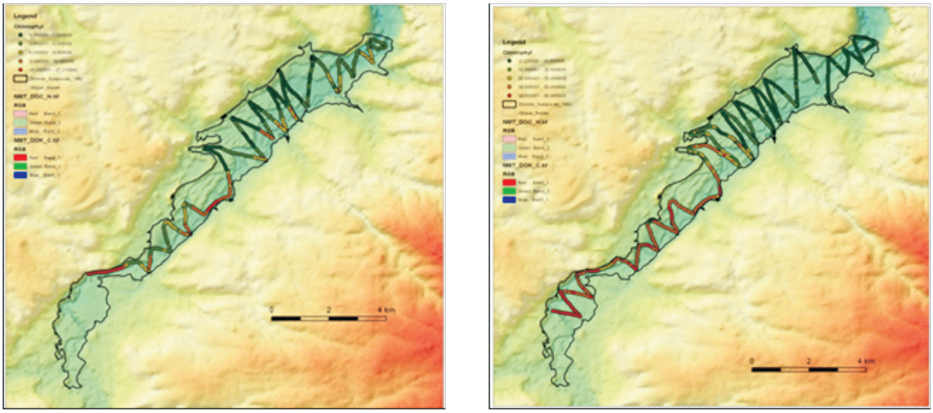

Fig. 3 Example of the map with the locations of each of the measurements made on 22.07.2015 and 02.09.2015 with the accompanying chlorophyll values (ug/l).

Then, for the purpose of enhance visualisation of the parameters in the lake, we interpolated the point-based values using the Surfer and ArcGIS software with the Spatial Analyst extension. This enabled us to produce maps showing the distribution of individual water parameters in the Sulejów Reservoir (Fig. 4).

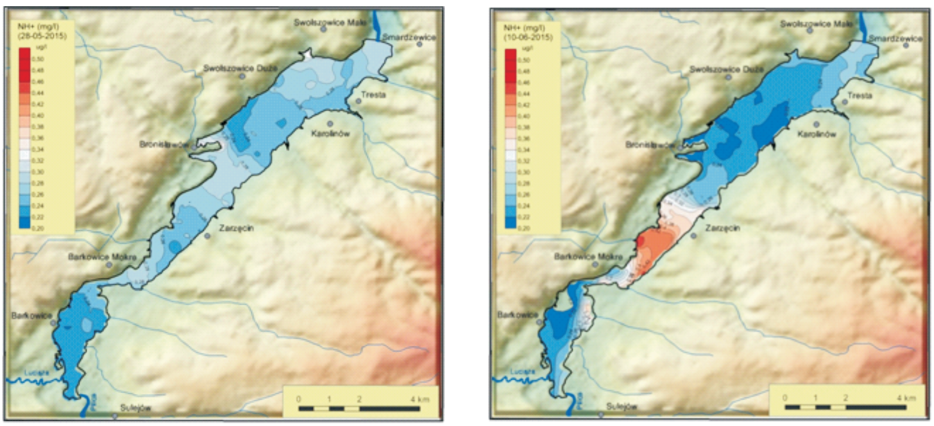

Fig. 4 NH_4^+ (mg/l) Distribution maps for 28.05.2015 and 10.06.2015

The representation of the spatial distribution of the Sulejów Reservoir water parameters on measurement days will enable the identification of the points of inflow and cumulation of compounds impacting the ecological status of the reservoir. For purposes of interpretation, the decision was made to also produce all maps in a unified scale for each measurement. These maps will enable tracking the changes in individual water parameters for the whole research period.

4. From the mathematical model to the model water management system

The use of mathematical modelling for solving the water quality problems is a great tool supporting the management of water resources. As a prognostic tool, the mathematical models enable the assessment of the changes in the ecological status of the studied water reservoir. As a diagnostic tool, they enable the description of very complex, real-time conditions in the analysed ecosystem.

The GEMSS software used in the MONSUL project is an integrated model composed of a three-dimensional hydrodynamic model and pollution transport model integrated into the geographical information and environmental data systems. The model is publicly available and was used for assessing the water quality around the world (http://www.erm-smg.com). GEMSS was developed in the mid-1980s as a platform providing information regarding the distribution of velocity fields and distribution of the concentrations of biogenic compounds. The family of GEMSS models includes the modules for: thermal analysis of waters, quality of water, tracking the distribution of particles, spillage of oil, chemical substances and toxins. The quality of inland surface waters and sea water can be accurately calculated by the model only with the complex 3-D hydrodynamic model and the corresponding pollution transport model.

The first step for the application of appropriate water quality simulations was to construct a three-dimensional geometry of the 17-kilometre Sulejów Reservoir (Fig. 5). For this purpose, the hydrodynamic module of the GEMSS model – HDM, water quality analysis uses the WASP model.

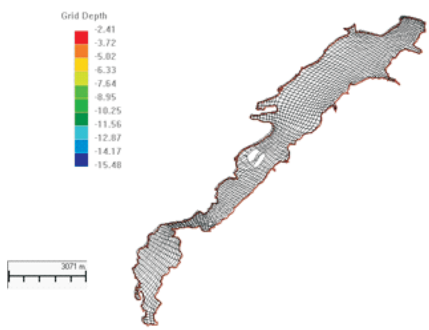

Fig. 5 Three-dimensional calculation grid generated in the GEMSS software.

The GEMSS model calibration was completed based on the data from 2007. The results confirm the assumptions and accurately represent the actual status. The example of calibration for two parameters: water temperature and nitrates concentration in the Sulejów Reservoir is presented in figure 6.

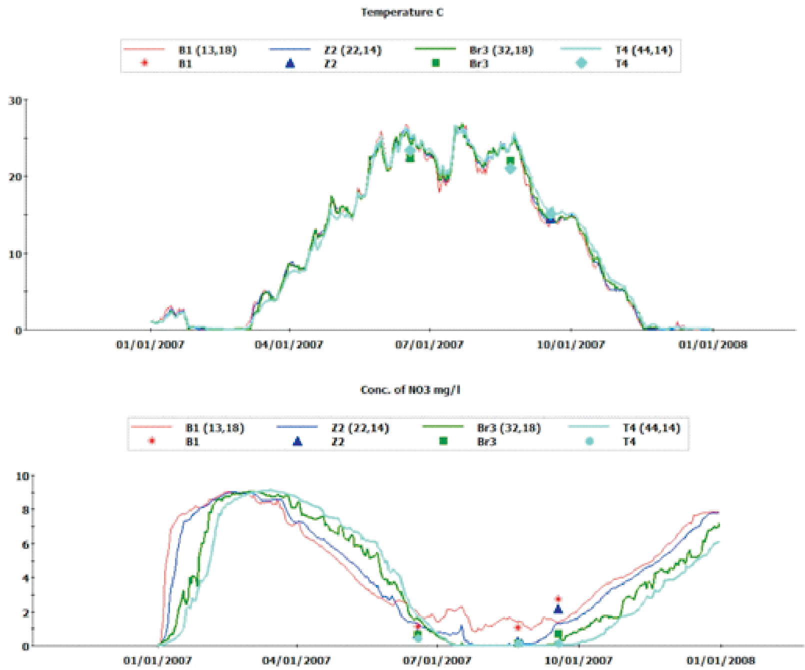

Fig. 6 Results of calibration for the 2007 data.

The simulations of the ecological status of the Sulejów Reservoir water were made based on the results of calibration. Necessary input data for the model, determining the eutrophication results are: a) water temperature, wind speed and direction, dew point temperature, b) hydraulic data (Manning's coefficient), meteorological data, c) initial and shore conditions, d) time series of incoming quality parameters, e) reaeration coefficients. All data were entered as daily values.

In the current model, it was assumed that the reservoir is encumbered with point-based pollution sources, mostly from the communal sewage treatment plants located in the vicinity of the Sulejów Reservoir. The changeability of the inflowing nutrients was expressed in kg/day and pertained to average values of biogenic load in consecutive months.

Figure 7 presents the initial simulation results for 2015 data. Figure 7 a) presents the temperature distribution in the reservoir in May in the scope from 19°C near the inlet of the reservoir (inflow of warmer water introduced with the tributaries) and 14°C in the lake (deeper) part of the reservoir. Figure 7 b) depicts the distribution of the nitrogen compounds concentrations. Higher values (0.27 mg NO3/dm^3) are observed in the transition part (between the river and lake sections) in May. This is the reasons for locating homesteads in this part of the lake. Furthermore, the nitrogen compound concentrations are several times lower in the vegetation period, compared to early spring and late autumn. This can be a result of a lower inflow of dissolved substances from the catchment area, increased absorption of nitrogen compound by the developing phytoplankton or increased intensification of the denitrification process. Nitrogen compounds in the reservoir are mostly of allochtonous origin (carried in by river waters, especially in the increased inflow periods).

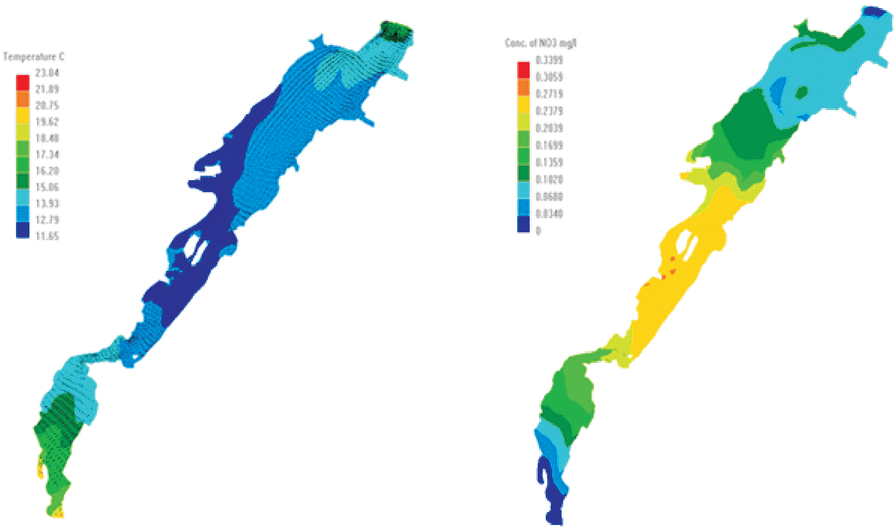

Fig. 7 Distribution of a) temperature and b) nitrates (NO_3) along the reservoir in May 2015.

The results of the simulations are complementary with the direct measurements of water quality and can be applied to support the decisions regarding water quality forecasts, especially regarding the course of eutrophication. They can also support making decisions regarding the changes in the water management of the reservoir, depending on the changing anthropogenic pressure.

5. Presentation of the methodology and scope of studies – meeting in Swolszewice

The MONSUL project team discussed the issues of presenting the methodology and scope of the Sulejów Reservoir water quality monitoring in the "Kruk" hotel in Swolszewice Małe near Tomaszów Mazowiecki on 24 June 2015. The attendees – representatives of all the towns and communes located by the reservoir, representatives of non-governmental organisations, environment administration, Sailing and Rowing Clubs, Polish Anglers Association, Landscape Parks Group and all interested parties could learn the first results and the method of presentation.

The team described the challenges posed by the reservoir water to the scientists in multiple presentations. The topic included: accuracy of measurements, methods of data collection and interpretation, lists and maps created using innovative IT solutions as well as the need to improve and modify the measurement systems. Further plans for the project and methods of sharing the research results were also presented.

After the meeting, the materials and presentations were uploaded to the project's website together with links to the pages: www.hydrowskaz.pl and www.aquamonitor.no/monsul, with tools for detailed and effective monitoring of the reservoir water status and quality parameters.

6. Results of the MONSUL project at the SDEWES 2015 Conference in Dubrovnik

Dr inż Mirosław Imbierowicz presented the results of the MONSUL project on the 10th Sustainable Development of Energy, Water and Environment Systems (SDEWES 2015) Conference in Dubrovnik from 26.09.2015 to 02.10.2015. The conference was attended by over 500 delegates from 50 countries, representing scientific institutions involved in, broadly defined, environment protection. The SDEWES conferences organised annually for over 10 years are interdisciplinary in character, i.e. they include a wide variety of topics, seemingly not closely related, but when treated comprehensively, enabling to discover and find solutions to many significant problems of today's world, such as: potable water deficit, food deficits, energy wasting, global climate changes, etc.

During the SDEWES 2015 Conference, on behalf of the group of co-authors and the whole MONSUL project research team, dr inż. M. Imbierowicz presented the lecture: "Analysis of factors affecting the ecological status of the Sulejow Reservoir based on continuous monitoring and an integrated 3D model of the artificial lake". During the presentation, he outlined the main objectives of the project as well as the methods of implementation. Dr inż. Imbierowicz also discussed the first results of the studies – measurements of the water quality obtained within the monitoring programme as well as the results of first computer simulations of the ecological status of the Sulejów Reservoir.

In the summary of the lecture and during the discussion, dr inż. M. Imbierowicz underlined the fact that the results of the project will be available in the future, however it can be stated today that the mathematical model of the Sulejów Reservoir developed within the MONSUL project will be a valuable tool for further research and may be used for effective and sustainable management of the water resources of the reservoir.

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