MIDDLE POMERANIAN SCIENTIFIC SOCIETY OF THE ENVIRONMENT PROTECTION

Rocznik Ochrona Środowiska

Volume 22. Year 2020 ISSN 1506-218X 648-668

Geographic Information System as a Tool to Support Environmental Monitoring and Management – Case Study of Bottom Sediments

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1. Introduction

Commonly observed, dynamic socio-economic development has a significant influence on the state of the natural environment. Human activity often has a negative impact on the environment and its components, both on a global and local scale. From the mid of the 20th century, human, who is a part of the natural environment, has increasingly began to analyse the range of problems resulting from water, soil and atmospheric air pollution, as well as the exploitation of natural resources. The consequences of these issues have been associated with health effects that can be observed with continuing, unsustainable economic growth (Gajos & Siekierka 2011). As a consequence, in 1987 the definition of sustainable development appeared in the report *Our Common Future* by the United Nations World Com-mission on Environment and Development, i.e. *which will ensure the fair satisfaction of the needs of modern society without compromising the ability to meet the needs of future generations* in the economic, ecological and social sphere (WCED 1987). The latest document on a sustainable development plan for the world is the 2030 Agenda signed at the 2015 UN Summit in New York. The agenda defines 17 goals, which assume, among others: protection of the natural environment and its resources (United Nations 2015). In accordance with the principles of sustainable development, the interaction between economic, social and environmental aspects should be non-invasive and harmonious in relation to other spheres. Unfortunately, the dynamic progress of civilization based on the continuous increase in the consumption of goods and services, the development of the automotive industry, the production of mass disposable products and the accumulation of waste often takes place without respecting the assets and resources of the natural environment (Rozpondek & Rozpondek 2017).

Currently, increasing environmental awareness of the society (Kłos 2015) has a significant impact on the development of research and investigations into new methods to solve problems related to environmental management. An important tool, which enables the collection, analysis and visualisation of environmental data, as well as its processes, is the Geographic Information System (GIS). This technology is applicable in various fields: administration, transport, security, natural environment, education, business, infrastructure and telecommunications, as well as in tourism and recreation. An example of utilising GIS in the problems of the natural environment is supporting the analyses carried out during the assessment of ecological vulnerability of particular areas (He et al. 2018), determining the type of land management, e.g. relating to the selection of the location for a landfill, taking into account its potential impact on the environmental components (Bahrani et al. 2016), assessing the suitability of an area for the development of renewable energy sources (Noorollahi et al. 2016) or modelling various types of threats affecting flora and fauna (Zeilhofer et al. 2011). The use of GIS supports environmental management by the interpretation of multifaceted relationships, modelling and forecasting changes in the natural environment and integrating various types of data. GIS helps to monitor the environment, including noise (Alam et al. 2020), air pollution (Alsahli & Al-Harbi 2017) and water (Mira et al. 2017) or the management of protected areas (Vaissi & Sharifi 2019). The main argument for the use of geostatistical methods in the analysis of the natural environment is the fact that they allow for the reduction in the costs of research, which are usually very high (Zawadzki 2011, Urbański 2012). Owing to the wide rage of possibilities enabling the combination of engineering and technical solutions with scientific knowledge, GIS technology is also used in evaluating the problematic aspects of bottom sediments monitoring.

Bottom sediments, due to their structure, which affects the increased accumulation of pollutants entering stagnant and running waters, are a valuable indicator of pollution monitoring (Förstner & Salomons 2010, Kennish 2017). It is considered that studies on the chemical composition of bottom sediments are often a better indicator of environmental pollution than the studies on the composition of water, which is more susceptible to time changes (Szarek-Gwiazda 2013, Szydłowski et al., 2017). As a result of human activity or natural processes, an imbalance between the water column and sediments is commonly observed. The aforementioned imbalance may lead to the activation of harmful substances accumulated in the sediments and cause secondary pollution of the reservoir water. As a consequence of this process, blockades in the use of water in the industry, municipal economy or agriculture may occur. Research on the bottom sediments and a detailed analysis of the obtained results allow identification of harmful human activities undertaken in the analysed region (Baran & Tarnowski 2013, Wojciechowska et al. 2017). These studies are extremely important as bottom sediments perform a number of roles in the natural environment, which include ecological, geochemical as well as economical functions (Szalińska 2011, Baran et al. 2016).

Accurate assessment of the state of bottom sediments, obtained from several dozen measuring stations, requires considerable labour and financial resources. The aim of the conducted studies was made to develop a bottom sediment monitoring network for selected water reservoirs of the Śląskie voivodeship (Ostrowy, Poraj and Dzierżno Duże reservoirs) using the GIS. It was assumed that the performed activities should allow achievement of the best ratio of the quantity and quality of the acquired data on the status of bottom sediments, while reducing the number of measuring stations.

2. Study area and methodology

The Silesian Voivodeship, located in the southern part of Poland, is characterized by the presence of many anthropogenic water reservoirs in its territory. The small share of natural lake basins results mainly from the ancient glacial nature of the terrain and the broadly understood anthropogenization of areas. The characteristic types of artificial water reservoirs in the Silesian Voivodeship include, among others dam reservoirs and reservoirs created as a result of land subsidence. The water reservoirs of the Silesian Voivodeship are commonly regarded as multifunctional objects (Rzętała 2008).

Due to its size, the industry of the Silesian Voivodeship has a significant impact on the level of contamination of surface water resources, and thus on the quality of bottom sediments. Bottom sediments are sensitive indicators of pollution monitoring because they can act as an absorber and carrier for substances polluting the aquatic environment (Kazimierowicz & Kazimierowicz 2014). Additionally, it should be noted that only some of the anthropogenic water reservoirs located in the Silesian Voivodeship are included in the research under the State Environmental Monitoring. Objects with an area greater than 250 ha belong to this group. There is a high need to include small tanks in monitoring studies. This is due to the fact that, like large water reservoirs, they are characterized by a significant degree of bottom sediment contamination. Therefore, the research covered three water reservoirs: Ostrowy, Poraj and Dzierżno Duże (Fig. 1, Table 1). Field work related to the collection of bottom sediment samples was carried out at the turn of July and August 2016.

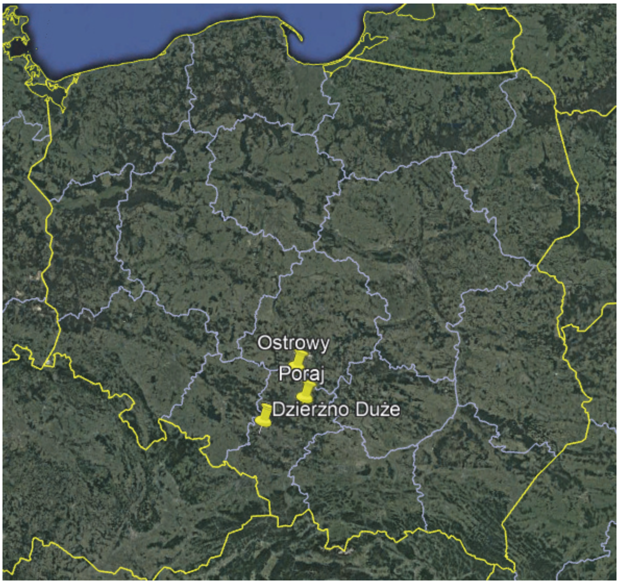

Fig. 1. The location of the Ostrowy, Poraj and Dzierżno Duże water reservoirs against the background of the map of Poland

Table 1. Features of the Ostrowy, Poraj and Dzierżno Duży water reservoirs

Feature	Reservoir		
	Ostrowy	Poraj	Dzierżno Duże
Longitude	19°01′42″E	19°14′02″E	18°33′32″E
Latitude	50°59′28″N	50°38′58″N	50°22′08″N
Year of putting into use	2003	1978	1964
Main river	Biała Oksza	Warta	Kłodnica
Area [ha]	39	550	615
Maximum depth [m]	5.3	7.4	16.5
Number of measuring points	31	46	52

To develop the grid for placing the sampling points, ArcGIS 10.2.2 software and an orthophotomap available as part of the WMS service by the Geoportal were utilised. Before starting the collection of research material, a field interview was conducted to check the availability of selected objects and confirm the possibility of collecting samples of bottom sediments. Due to the elongated shape of the Ostrowy water reservoir, the bottom sediment sampling grid was planned on the basis of cross-sections. Additional samples were also collected in the vicinity of the dam, in the bay and at the inlet and outlet of the reservoir. In total, material was collected for the analyses from 31 out of 32 planned measurement points from the depth of 0.3 to 5.3 m. The collection of sample number 31 was not possible due to the inaccessibility of the area due to abundant water vegetation (Fig. 2a). In the remaining objects, the measurement network was developed on the basis of a square grid. In the case of the Poraj reservoir, the mesh side was approximately 300 m, and in the Dzierżno Duże reservoir – approximately 350 m. Due to the inaccessibility of the area, the location of the previously planned points was slightly changed. From the Poraj reservoir, samples of bottom sediments were collected at 46 designated measurement points from the depth of 0.4 m to 7.4 m (Fig. 2b). In the case of the Dzierżno Duże reservoir, material was collected at 52 out of 56 planned points from a depth of 0.3 m to 16.5 m below the water table. The uptake at points 19, 36, 55 and 57 was prevented due to non-blistering ground conditions (too shallow bottom, lush water vegetation) (Fig. 2c).

Samples of bottom sediments were collected using KC Denmark's specialist Van Veen bottom sediment catcher lowered on a rope. A bottom sediment catcher with a hoist and a vessel were part of the measuring station, thanks to which samples of bottom sediments were obtained. Three samples were taken from each selected point, which only after mixing constituted a representative sample. The collected bottom sediment samples were dried in air-dry conditions, and then pre-sieved through a 2 mm sieve. They were subsequently dried in an oven at 105°C to constant weight and milled in a vibratory mill to sludge fractions with particle diameters of <0.2 mm. Three samples were prepared for each measurement point. The total content of heavy metals (Cd, Cr, Cu, Ni, Pb, Zn) in bottom sediments was determined using the ICP-OES IRIS Thermo plasma spectrophotometer. Royal water was used for the extraction, in accordance with standard 11466:2002 (a mixture of concentrated hydrochloric acid and nitric acid in a 3:1 volume ratio). Mineralisation was carried out at 180°C, over 30 minutes, using a Berghof high pressure microwave mineraliser (Rozpondek & Rozpondek 2017, Rozpondek et al. 2017, Rozpondek & Rozpondek 2018).

Currently, no strictly defined classification of the bottom sediments exists in the Polish legislation in relation to the heavy metal content specified therein. Until 2012, the legal regulation of the aforementioned field had been the Regulation of the Minister of the Environment from the 16th of April 2002 concerning the types and concentrations of substances that cause contamination of the spoil. Since 2013, as a part of the State Environmental Monitoring, the assessment of the quality of bottom sediments in the context of their heavy metal pollution has been based on geochemical methods (Bojakowska 2001). This classification is based on the comparison of the content of the polluting components in the sludge with those found in natural conditions or slightly contaminated sediments. The concept, which explains the natural content of an element in the environment is the geochemical background. This term defines the amount of metal originating from biochemical, geological and other natural processes. In the case of water and bottom sediments, the processes responsible for the concentration of the element as geochemical background values include natural atmospheric deposition, uncontaminated erosion of the river bank or the inflow of natural organic materials.

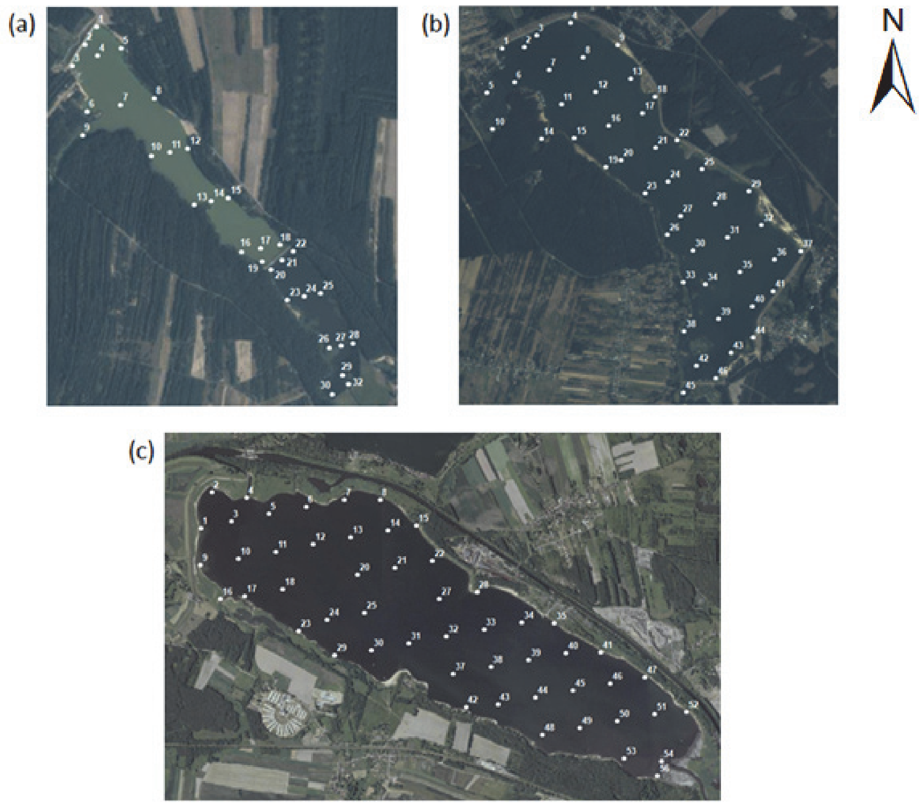

Fig. 2. Research objects with the measurement networks (a) Ostrowy, (b) Poraj and (c) Dzierżno Duże

Table 2. Qualitative classification of bottom sediments according to geochemical classification (mg/kg) (Bojakowska 2001)

Elements	Geochemical background	I class	II class	III class	IV class
Cd	<0.5	<1	3.5	6	>6
Cr	5	<20	<100	<500	>500
Cu	6	<40	100	200	>200
Ni	5	<16	40	50	>50
Pb	10	<30	100	200	>200
Zn	48	<200	500	1000	>1000

The geochemical classification of bottom sediments distinguishes pollution classes (Table 2, Table 3). When determining marginal values, it is assumed that values greater than the sum of the mean content of an element and two standard deviations determined for the analysed data set are considered as unnatural content of the element in the natural environment. The sediment is classified as contaminated when values higher than the permissible content even for one element are observed.

Table 3. Class of geochemical classification of bottom sediments with their characteristic features

Class	Degree of sediment pollution	The concentration of metals in relation to the geochemical background
I	slightly polluted	from 2 to 10 times higher
II	moderately polluted	from 10 to 20 times higher
III	polluted	from 20 to 100 times higher
IV	heavily polluted	> 100 times higher

Taking into account the results of the research on the total content of heavy metals and their geochemical classification, bottom sediment monitoring networks of the Ostrowy (Rozpondek & Rozpondek 2017), Poraj (Rozpondek et al. 2017) and Dzierżno Duże reservoirs (Rozpondek & Rozpondek 2018) were planned. Based on the obtained spatial distributions, the location of points was selected, which should be considered in further studies – the inlet and outlet zones of the reservoir, as well as locations indicating achievement of limit values between individual geochemical classes. In the search for the optimal solution, it was assumed that the network enabling collection of reliable results on the sludge quality, while minimising financial outlays, should not exceed 25% of measurement points from the base year. In order to define the quality and accuracy of the planned network, a visual assessment of the obtained spatial distributions was used. A comparison of the classification of measurement stations with respect to the quality assessment of the geochemical criterion in relation to the selected heavy metal real data, as well as the values obtained on the basis of the simulation was made. Interpolation of spatial data of the planned bottom sediment monitoring network was performed using the weighted reverse distance method.

3. Results and discussion

For the Ostrowy reservoir, based on the assumption that the bottom sediment monitoring network should consist of 25% of baseline measurement points, no satisfactory results were obtained. Due to the elongated shape of the facility and the layout of the basic measurement network based on cross sections, the utilised interpolation algorithm did not reflect the actual state associated with the content of heavy metals in bottom sediments. On this basis, it was decided to increase the number of points making up the monitoring network from 8 to 10 positions, which constituted 32% of the samples of the basic measurement network. To a large extent, bottom sediments of the analysed facility showed no (Cd), weak (Cu) or medium pollution (Pb, Zn) caused by the presence of the selected heavy metals, which is associated with the obtained comparative analysis results. The significant level of contamination resulting from the chromium and nickel content caused that the range of the classification changes varied from 0 to 5 test stands (Fig. 3).

The results indicating the high quality of the conducted simulation were obtained in the scope of estimating the content of copper, zinc and lead in the bottom sediments of the Ostrowy reservoir. Discrepancies were found in the classification of simulation results in relation to the actual test results for the nickel and chromium content. In the case of these elements, the size of the class indicating no pollution was underestimated, whereas the class informing about contaminated (Cr) and highly contaminated sediments (Ni) was overestimated. Visual assessment of the obtained spatial distributions (Fig. 4) indicates high quality of the planned measurement network.

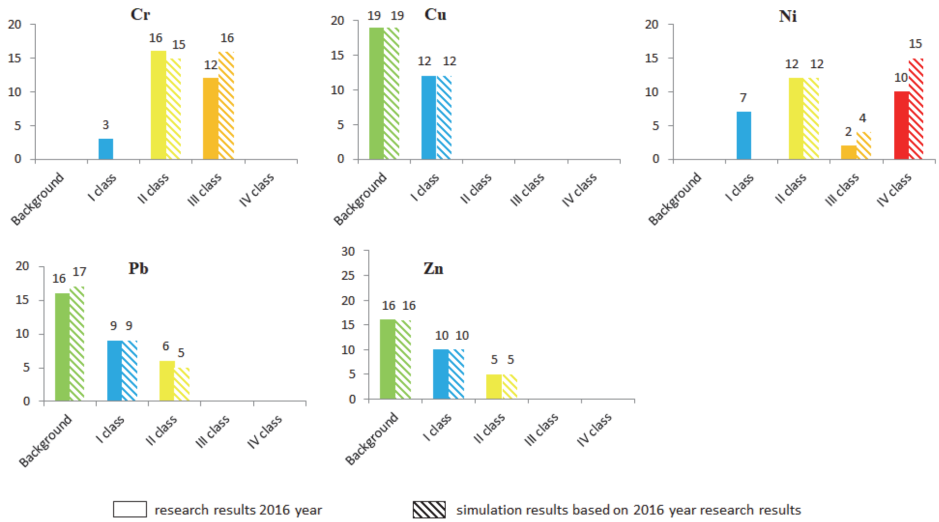

Fig. 3. Comparison of the classification of the total heavy metal content in the bottom sediments of the Ostrowy reservoir on the basis of the test results and the simulation results (vertical axis – number of measuring stations, horizontal axis – final assessment according to the geochemical classification)

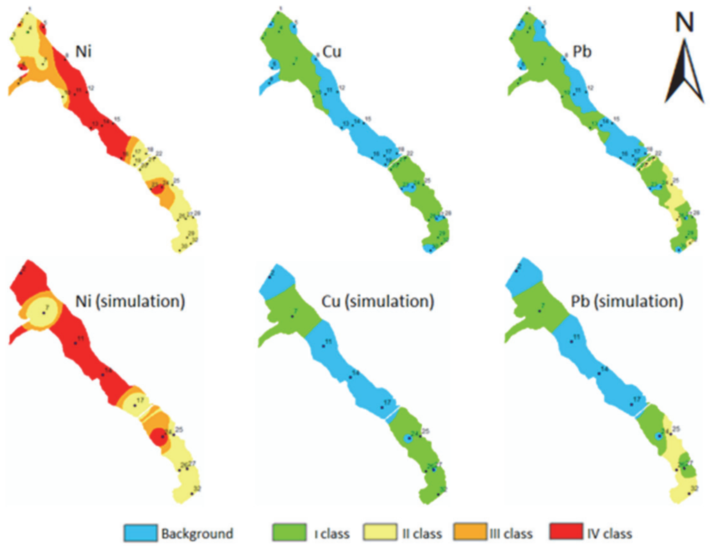

Fig. 4. The spatial distributions of the contents of selected heavy metals in the bottom sediments of the Ostrowy reservoir were obtained on the basis of the real data and simulation results

Based on the classification of the measuring positions of the Poraj reservoir in relation to the quality assessment of the geochemical criterion, significant changes were found in the classification of the individual measuring points. The range of the changes relating to the increase or decrease in the size of a given class was between 0 to 19 test stands (Fig. 5).

The simulation of the measuring network of the Poraj reservoir was based on 28% of the base points (13 stands). Utilising a smaller number of test stands did not allow for collection of satisfactory results. It was found that the results of the simulation lead to an underestimation of the value for selected heavy metals, particularly in the case of the geochemical background (Cu, Ni, Pb) and first class (Cd, Cr, Zn), while the overestimation of values was obtained for first (Cu, Ni), second (Cd, Cr, Pb) and third class (Zn) of geochemical criteria (Fig. 5).

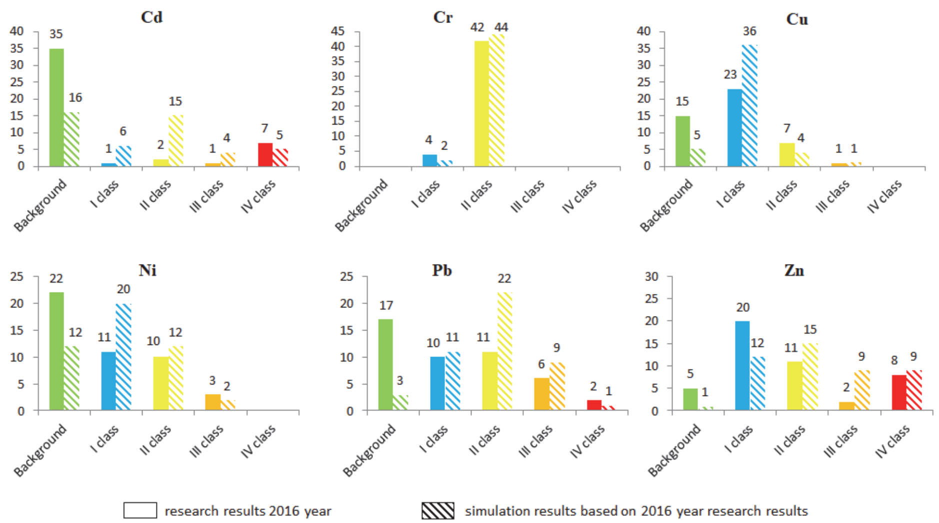

Fig. 5. Comparison of the classification of the total heavy metal content in the bottom sediments of the Poraj reservoir on the basis of the test results and the simulation results

Bottom sediments of the Poraj reservoir were characterised by point increase in heavy metal content, which affected their values obtained in the process of data estimation. However, visual assessment of the spatial distributions (Fig. 6), which were obtained on the basis of 13 test stands, allows the selection of areas that should be included in systematic research.

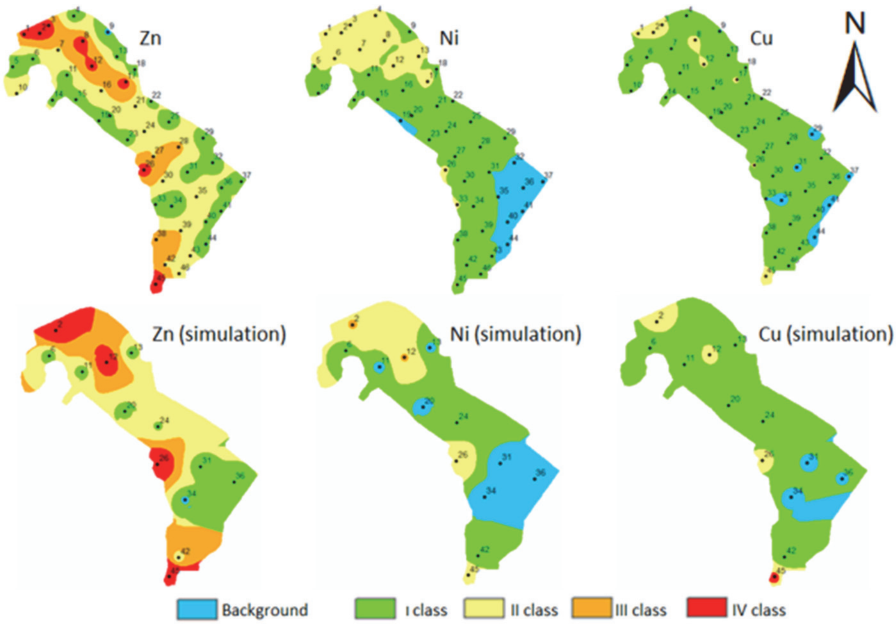

Fig. 6. The spatial distributions of the contents of selected heavy metals in the bottom sediments of the Poraj reservoir were obtained on the basis of the real data and simulation results

The bottom sediment monitoring network in the case of the Dzierżno Duże reservoir was constructed on the basis of 25% of base points, i.e. a network consisting of 13 test stands. Based on the real test results and the simulation outcomes, it was found that changes in the classification of the individual measuring positions are in the range of 0 to 16 (Fig. 7).

Based on the obtained outcomes, it was found that the results of the simulation lead to an underestimation of the values for individual elements, mainly for the geochemical background (Cd, Cu, Ni, Pb) and first class (Cr, Ni, Zn), while the value was primarily increased for the second class of the geochemical criteria (Cr, Cu, Ni, Pb, Zn) (Fig. 7). The largest discrepancies in the classification of the simulation results in relation to the real test results were found for the chromium and nickel content, and the smallest for the level of cadmium, copper and zinc content. Based on visual assessment of the spatial distributions of the heavy metal content obtained on the basis of the simulation (Fig. 8), it was determined that they enable planning of high-quality research, while minimising the financial outlays allocated to it.

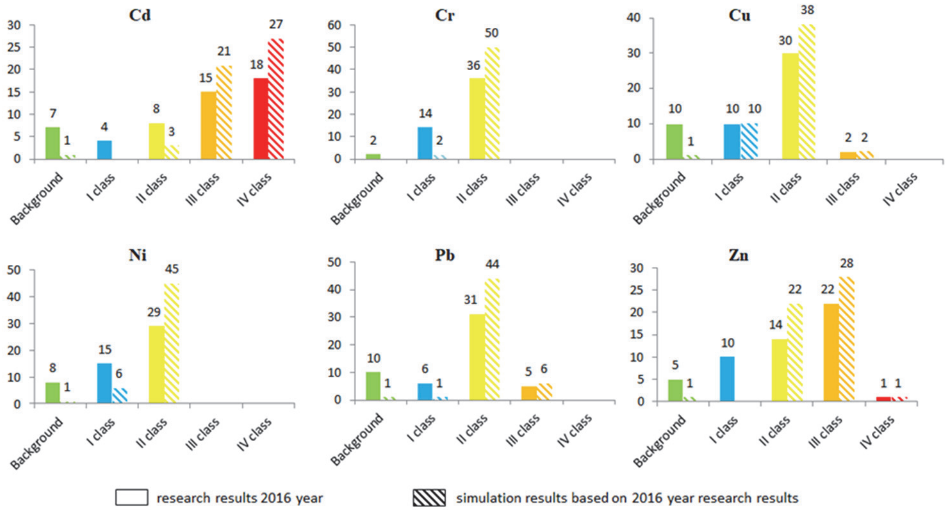

Fig. 7. Comparison of the classification of the total heavy metal content in the bottom sediments of the Dzierżno Duże reservoir on the basis of the test results and the simulation results

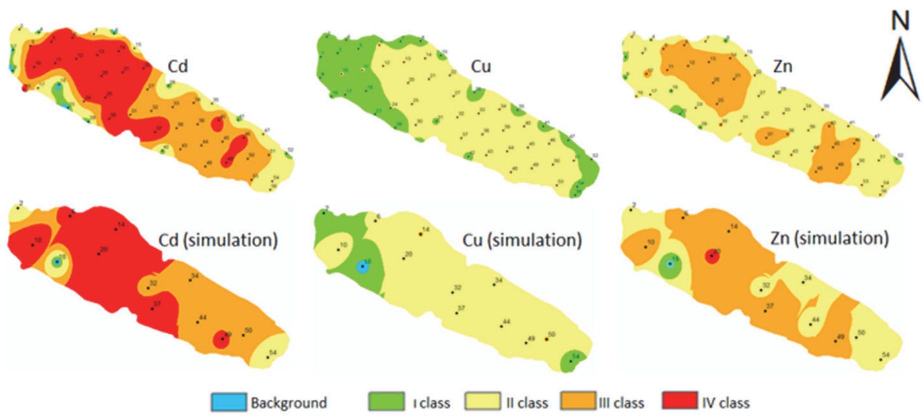

Fig. 8. The spatial distributions of the contents of selected heavy metals in the bottom sediments of the Poraj reservoir were obtained on the basis of the real data and simulation results

The overestimation of the simulation results is conditioned by the specificity of the interpolation method used, the algorithm of which assigns the value to a point in space based on the result of the estimation of the values from the test stands from the previously chosen neighbourhood. The methodology for selecting points composing the bottom sediment monitoring network, included test stands in the inlet and outlet areas of the reservoirs and in the areas characterised by limit values between particular geochemical classes. Therefore, obtaining overestimated values, particularly for sediments characterised by high levels of pollution, was an unavoidable stage of the study. A significant increase in the number of points making up the measurement network would allow for achieving higher quality results. However, this option was rejected due to the fact that it contradicts the adopted assumptions concerning minimising the financial outlays allocated to the research. Visual assessment of the spatial distribution of the content of selected heavy metals in the bottom sediments of the analysed facilities enabled the selection of areas that should be covered by systematic research. This indicates an important role of the employed criterion in assessing the quality of the planned monitoring network of the bottom sediments of the Ostrowy, Poraj and Dzierżno Duże reservoirs (Rozpondek 2019).

The latest literature reports on the content of heavy metals in other Polish water reservoirs, including geochemical classification, are shown below (Table 4).

The geochemical class of the bottom sediments of selected water reservoirs was determined based on the maximum value of the total content of a given element. The geochemical monitoring network, which operates under the State Monitoring subsystem, i.e. Inland surface water quality monitoring, consists of river sediments and sediments of selected lakes and water reservoirs. As a part of this project, bottom sediments of artificial water reservoirs include the facilities of large volumes or these utilised for water supply purposes. The presented data (Table 2), as well as our own research, show that bottom sediments of water reservoirs, regardless of the size, are characterised by high levels of pollution caused by heavy metal content.

Table 4. Content of heavy metals in bottom sediments (mg/kg)

Reservoir		Cd	Cr	Cu	Ni	Pb	Zn	Area [ha]
Łoje (Cymes et al. 2017)	Min. – Max	0.1-0.8	3.4-33.0	1.2-19.0	2.1-22.7	6.3- 41.0	6.5-88.0	5
	Avg.	0.4	11.9	7.6	9.6	20.4	41.4	
Września (Sojka et al. 2019)	Min. – Max.	0.2-0.7	4.0-6.1	3.7-18.7	2.5-9.8	7.0-32.8	27.8-1990.4	33
	Avg.	0.4	6.1	9.4	5.5	15.2	678.4	
Środa (Sojka et al. 2019)	Min. – Max.	0.1-0.3	1.7-9.3	1.4-8.7	1.0-6.0	2.8-13.0	50.8-1131.7	39
	Avg.	0.2	4.8	4.6	3.5	7.4	357.5	
Ostrowy (Rozpondek & Rozpondek 2017)	Min. – Max.	–	10.4-283.7	0.8-31.9	7.9-128	<* -57.7	7.0-441.6	39
	Avg.	–	93.5	9.0	41.8	15.9	96.9	
Pakosław (Sojka et al. 2019)	Min. – Max.	<*-0.1	0.7-4.7	0.3-4.7	0.4-4.8	0.9-5.3	8.2-510.7	54
	Avg.	0.1	2.0	2.0	2.0	2.6	221.7	
Besko (Piwińska et a. 2018)	Min. – Max	0.4-1.3	38.4-46.3	2.5-31.8	29.2-35.3	–	75.8-81.9	130
	Avg.	0.7	42.3	26.7	31.5	–	79.0	

Background I class II class III class IV class

* value below detection threshold

Table 5. cont.

Reservoir		Cd	Cr	Cu	Ni	Pb	Zn	Area [ha]
Rzeszów (Bartoszek et al.2015)	Min. – Max	2.1-3.1	46.9-67.7	24.4-38.6	28.5-42.9	37.8-63.9	79.6-133.6	203
	Avg.	2.5	56.3	32.7	35.6	53.5	103.9	
Brody Iłżeckie (Smal et al. 2015)	Min. – Max.	0.3-6.4	<*-106.0	1.3-47.7	<*-55.4	36.3-116.0	21.4-826.0	204
	Avg.	2.5	41.4	16.6	14.3	69.2	354.0	
Chańcza (Baran et al. 2011)	Min. – Max.	<*-0.9	5.3-30.2	6.5-89.6	5.1-30.2	13.9043.2	61.6-212.0	340
	Avg.	0.5	18.4	40.7	18.4	23.8	112.1	
Poraj (Rozpondek et al. 2017)	Min. – Max.	<*-9.1	16.7-74.9	3.0-105.0	<*-45.1	2.4-253.3	19.6-3058.4	550
	Avg.	1.3	31.9	17.2	11.6	50.6	461.4	
Rybnik (Baran et al. 2016)	Min. – Max.	0.1-15.7	2.9-132.7	33.5-1506.0	3.3-68.8	35.7-136.8	79.7-1796.0	555
	Avg.	3.7	32.2	258.3	20.4	67.6	439.4	
Dzierżno Duże (Rozpondek & Rozpondek 2018)	Min. – Max.	0.2-22.7	2.3-88.2	0.4-100.9	<*-36.5	0.9-134.4	13.3-1056.3	615
	Avg.	5.1	36.3	40.1	16.2	56.6	410.0	

Background I class II class III class IV class

* value below detection threshold

Planning of the bottom sediment monitoring network is particularly important for facilities with a small area (less than 250 ha), which are not covered by the State Environmental Monitoring research. Due to their functions, as well as the rapid rate of silting and the necessity for periodic removal of the silt, systematic and detailed monitoring of the properties of bottom sediments of small water reservoirs, plays an important role. Moreover, a deliberately planned collection of bottom sediment samples is also justified for large water reservoirs. According to the data of the State Environmental Monitoring between 2010 and 2015, bottom sediments of 58 dam reservoirs were tested at 74 test stands (GIOŚ 2017). This indicates that there was an average of 1.3 test stands per water reservoir. The use of this number of points allows for reduction in the amount of labour and financial resources; however, it is not the basis for a precise analysis of the condition of the bottom sediments in the examined facility. The research conducted in the current study indicates that the pollution of the bottom sediments is often characterised by point or area character. Therefore, the exact designation of the quality of the matter residing at the bottom of artificial water reservoirs is associated with the collection of a significant amount of bottom sediment samples (Rozpondek 2019). The proposed solution of developing a network of bottom sediment monitoring points is an example of precise activity supporting environmental management in accordance with the principles of sustainable development.

4. Summary

In recent years, there has been a continuous interest in the issues related to the natural environment, including in particular issues related to determining the level of its pollution, as well as defining innovative solutions aimed at monitoring its condition and preventing degradation, as well as managing its elements. One of the tools enabling such activities is the GIS, which is an important diagnostic tool for the state of the environment, as well as facilitates inference about the mechanisms and processes occurring in it in the environment. Based on the research, the following conclusions were conducted:

- The material collected at the bottom of the Ostrowy, Poraj and Dzierżno Duże reservoirs is characterized by a high concentration of heavy metals, which proves a significant level of contamination. For this reason, it is recommended that local authorities take into account the determination of sources of pollution in their policies and take decisions related to measures to prevent their formation, as well as monitor the condition of bottom sediments.
- Spatial distributions of the concentration level of heavy metals in bottom sediments of selected water reservoirs can be used to restore the condition of water ecosystems to the proper condition. On the basis of the adopted criteria within the Ostrowy, Poraj and Dzierżno Duże reservoirs, areas showing a

different level of pollution were identified. In the case of planning the reclamation of water reservoirs, this knowledge will make it possible to narrow the reclamation activities to particularly degraded zones. In this way, human interference in the natural environment will be limited. Zones within the reservoir with no bottom sediment contamination will remain intact. These actions are an example of the fulfillment of the environmental protection assumptions contained in the Polish Environmental Protection Law, and therefore should be taken into account by local authorities when managing the analyzed water reservoirs.

- Visualisation of laboratory test results using the GIS provides a clear message about the quality of the bottom sediments. Making these types of studies available to the public administration bodies, as well as the public will increase their environmental awareness.
- Based on the comparison of the classification of test stands in relation to the quality assessment of the geochemical criterion of real data (2016), as well as the values obtained on the basis of the simulation, it was determined that the most satisfactory results were obtained for the bottom sediments of the Ostrowy reservoir. The significant level of contamination resulting from the chromium and nickel content caused that the range of classification changes varied from 0 to 5 test stands. In the case of other water reservoirs, a higher scope of changes was found in the adopted comparative analysis (Poraj 0-19 stands, Dzierżno Duże 0-16 stands). This phenomenon is associated with a significant range of the base data resulting from high pollution of the bottom sediments with individual heavy metals (Poraj – Cd, Pb, Zn, Dzierżno Duże – Cd, Zn).
- Considering the conducted research, it was found that the sustainable management of the environment by determining the bottom sediment monitoring network of the Ostrowy, Poraj and Dzierżno Duże reservoirs should be based on an individual research approach for each of the facilities. This necessity results from the differential level of heavy metal content in the analysed material.
- The development of a bottom sediment monitoring network is an innovative solution based on the assumption that data on the quality of bottom sediments is collected in a financially justified manner.
- Although the study uses the geochemical classification of the quality of bottom sediments used in Poland, the proposed methodology for the bottom sediment monitoring network is so universal that it can be successfully used internationally by countries using a different type of bottom sediment quality classification of water reservoirs.

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Abstract

The aim of the conducted studies was made to develop a bottom sediment monitoring network for selected water reservoirs of the Silesian voivodeship (Ostrowy, Poraj and Dzierżno Duże reservoirs). Based on the obtained spatial distributions, the location of points was selected, which should be considered in further studies. In the search for the solution, it was assumed that the network enabling collection of reliable results on the sludge quality, while minimising financial outlays, should not exceed 25% of measurement points from the base year. In order to define the quality and accuracy of the planned network, a visual assessment of the obtained spatial distributions was used. A comparison of the classification of measurement stations with respect to the quality assessment of the geochemical criterion in relation to the selected heavy metal real data, as well as the values obtained on the basis of the simulation was made. Comparative analysis showed a high range of changes in the classification of measuring positions (Ostrowy 0-5 positions, Poraj 0-19 positions, Dzierżno Duże 0-16 positions). This fact is associated with a significant range of base data resulting from high pollution of bottom sediments with individual heavy metals (Ostrowy – Cr, Ni, Poraj – Cd, Pb, Zn, Dzierżno Duży – Cd, Zn). Considering the conducted research, it was found that the sustainable management of the environment by determining the bottom sediment monitoring network of the Ostrowy, Poraj and Dzierżno Duże reservoirs should be based on an individual research approach for each of the facilities. The research allowed to state that GIS has a significant impact on decision-making in the field of environmental management.

Keywords:
geochemical classification, heavy metals, decision making

System Informacji Geograficznej, jako narzędzie wspomagające monitoring i zarządzanie środowiskiem – przykład osadów dennych

Streszczenie

Celem przeprowadzonych badań była próba opracowania sieci monitoringu osadów dennych wybranych zbiorników wodnych województwa śląskiego (zbiornik Ostrowy, Poraj i Dzierżno Duże). Na podstawie uzyskanych rozkładów przestrzennych całkowitej zawartości metali ciężkich i ich geochemicznej klasyfikacji wytypowano lokalizację punktów, które powinny zostać uwzględniane w dalszych badaniach. W poszukiwaniu rozwiązania założono, że sieć pozwalająca na uzyskanie wiarygodnych wyników jakości osadów, przy jednoczesnej minimalizacji nakładów finansowych, nie powinna przekraczać 25% punktów pomiarowych pochodzących z roku bazowego. W celu zdefiniowania jakości i poprawności zaplanowanej sieci posłużono się wizualną oceną uzyskanych rozkładów przestrzennych. Dokonano również porównania klasyfikacji stanowisk pomiarowych względem oceny jakości kryterium geochemicznego w odniesieniu do wybranego metalu ciężkiego danych rzeczywistych, jak i wartości uzyskanych na podstawie przeprowadzonej symulacji. Analiza porównawcza wykazała wysoki zakres zmian klasyfikacji stanowisk pomiarowych (Ostrowy 0-5 stanowisk, Poraj 0-19 stanowisk, Dzierżno Duże 0-16 stanowisk). Zjawisko to związane jest ze znaczną rozpiętością wartości danych bazowych wynikającą z wysokiego zanieczyszczenia osadów dennych poszczególnymi metalami ciężkimi (Ostrowy – Cr, Ni, Poraj – Cd, Pb, Zn, Dzierżno Duże – Cd, Zn). Na podstawie przeprowadzonych badań stwierdzono, że zrównoważone zarządzanie środowiskiem poprzez wyznaczanie sieci monitoringu osadów dennych zbiornika Ostrowy, Poraj i Dzierżno Duże powinno odbywać się w oparciu o indywidualne podejście badawcze w odniesieniu do każdego z obiektów. Przeprowadzone badania pozwoliły na stwierdzenie, że GIS ma istotny wpływ na podejmowania decyzji w zakresie zarządzania środowiskiem naturalnym.

Słowa kluczowe:
klasyfikacja geochemiczna, metale ciężkie, podejmowanie decyzji