AKADÉMIAI KIADÓ

# Current state of small water reservoir from technical and ecological viewpoint

Zuzana Sabová[1], Zuzana Németová[1*], Tatiana Kaletová[2] and Silvia Kohnová[1]

[1] Department of Land and Water Resources Management, Faculty of Civil Engineering, Slovak University of Technology, 81107, Bratislava, Slovakia

[2] Department of Technical Informatics, Faculty of Engineering and Information Technology, Slovak University of Agriculture, 94901, Nitra, Slovakia

Pollack Periodica • An International Journal for Engineering and Information Sciences

16 (2021) 3, 58–63

DOI: 10.1556/606.2021.00313


Received: December 8, 2020 • Revised manuscript received: February 22, 2021 • Accepted: March 1, 2021
Published online: May 29, 2021

ORIGINAL RESEARCH PAPER

**ABSTRACT**

The objective of the study is an assessment of a Ratka small water reservoir in Slovakia by using two main aspects, i.e., the hydrotechnical, geotechnical and environmental aspects.

An evaluation of the actual state of a small water reservoir was solved in a complex way. Based on the field measurements, the quality of surface water was controlled in order to check if the surface water quality indicators meet the requirements of government regulations. In addition to the terrain measurements, laboratory measurements were performed. The results assess the actual state of the small water reservoir in details, including an assessment of the water quality with proposed measures for improving the condition of the water reservoir.

**KEYWORDS**

small water reservoir, water quality, hydrotechnical and geotechnical evaluation, technical state, chemical analysis

*Corresponding author.
E-mail: zuzana.nemetova@stuba.sk

AKJournals

## 1. INTRODUCTION

It is well known that water is the one of the most important substances for the planet's ecosystem and human beings. Water in natural environment contains not only molecules of $H_2O$, but also is defined as a complex of organic and inorganic substances and contains materials of chemical (inorganic substances) and physical (electrolytes and non-electrolytes) compositions [1].

There are different sources of water, i.e., rivers or lakes, springs, surface water, rock catchment areas, rock holes, excavated dams, rainwater tanks, and artesian bores. Nowadays, the oceans hold 96.5% of all the Earth's water; the fresh water on the planet amounts to 2.5%, and the remaining 1% is part of the groundwater [2]. All of water on the Earth, less than 1% is drinkable. Fresh water can be further separated into three main segments. The first one, where the water is stored, represents the cryosphere, which includes about 68.5% of all the fresh water on Earth (ice sheets and glaciers). The second segment includes land reservoirs in the form of surface water (lakes and rivers) and contains approximately 31% of fresh water. The last segment, which is called the atmosphere, represents the smallest amount of fresh water (only 0.1%). In these segments, 99.9% of the water exists in the form of vapor, and only 0.1% of the water in the atmosphere is stored in clouds in liquid and solid forms. These tiny quantities of water have a significant influence on the water energy balance of the planet and impact on the fluxes to and from all the other water reservoirs as well [2]. Because the quality of water resources is decreasing, water management plays an important role in ensuring their protection, control and sustainable development [3]. The quality and quantity of water resources is directly connected to the quality of life for humans, plants and animals [4].

Therefore, the fundamental concept of water reservoirs lies in the water supply, the protection from floods of valleys downstream, scenic beauty, fish and wildlife habitats, the establishment of an aquatic environment, and control of the natural character of water flows.

According to [5] a water reservoir can be of natural or artificial origin where water can be filled in or emptied at certain times. Water reservoirs can be divided into large and small reservoirs. It is obvious that large reservoirs have strong impacts on hydrology on regional and global scales and have an impact on decreasing global runoff of approximately 2% [6].

However, small water reservoirs and lakes (with areas of less than 0.1 $km^2$) cover in total larger area than large reservoirs [7] and influence the natural water cycle that would occur without reservoirs. In order to understand how small reservoirs can affect river flows on a basin scale, it is necessary to understand the operation and behavior of every single reservoir [8].

Nowadays, like other elements of a natural or artificial character, water reservoirs are also affected by climate change. The response to climate change is different between natural and artificial water bodies, since the storage and outflow of artificial water reservoirs are actively managed [9]. Climate change impacts water reservoirs in several ways, i.e., biological changes in the phytoplankton community [10] and increasing water temperatures [11] boost the processes inducing the eutrophication of water bodies [12]. Most of these changes can lead to decreasing water quality [13] and to reinforcing global warming [14]. The aim of the study lies in the evaluation and assessment the current hydrotechnical and geotechnical condition of the Ratka water reservoir, together with the water quality analysis in the reservoir and its surroundings. The intention of the study is to assess the individual components of the small water reservoir in the sense of their technical condition and the purpose for which they were built.

## 2. STUDY SITE AND INPUT DATA

### 2.1. Characteristics of the village of Ratka

The village of Ratka is located in the southern part of the Slovak Republic in the district of Lučenec and the region of Banska Bystrica. The size of the area is 24.05 $km^2$ with its lowest altitude of 190 m.a.s.l. and with the highest altitude of 390 m.a.s.l. The village is located in the western part of the Cerová highlands. The research zone belongs to a continental climate with warm summers and cold winters [15]. The research area falls into the basin of the river Ipel' with Babský creek as its main water stream; it is a left tributary of the river [15]. The length of the Babský creek is 10.04 km with 33.35 $km^2$ as the total size of the catchment area [16]. One of Babsky Creek's tributaries is the Cerová tributary (the hydrological sequence number of water stream 4-24-01-111) on which the Ratka small water reservoir was built [15].

*Table 1.* Technical parameters of the Ratka small water reservoir

| Characteristics of the Ratka water reservoir | Value |
|---|---|
| The length of the dam crown | 83 m |
| The width of the dam in the crown | 3.2 m |
| Maximum height of the dam in the axis | 4.5 m |
| The total volume of the dam | 3,500 $m^3$ |
| Location of the discharge object | 35.5 m |
| Length of the footbridge | 11 m |
| Width of the spillway | 2.0 m |
| Location of the spillway | 13 m |
| Length of operation shift | 6.5 m |
| Depth of slope | 1.54 m |
| Length of spill | 26 m |
| Depth of spill | 50 cm |
| Length of stilling basin | 6.5 m |

### 2.2. Characteristics of the Ratka small water reservoir

The Ratka water reservoir was built in the years 1965–1966 for the main purpose of accumulating water for irrigation. The water structure was never used for this purpose, because the irrigation systems were never built. Other purposes of the water reservoir are flood protection and fire protection. The constant accumulated volume of the reservoir is 17,000 $m^3$ at the maximum level. In 2008, a reconstruction of the water reservoir was carried out, and it was found that the reservoir was considerably clogged with sediments 70–80 cm thick. Nowadays, the reservoir is used for fishing. The administrator and operator of the water reservoir is the Slovak Water Management Company [17]. The characteristics of the technical parameters of the Ratka reservoir are shown in Table 1.

## 3. MATERIAL AND METHODS

### 3.1. Field measurements

Field measurements were performed in order to evaluate the characteristics of the water properties as an important component of the ecological evaluation of the Ratka small water reservoir.

Three sampling points were selected (Fig. 1). The first point is represented by the Cerová water stream, which is located 300 m before the estuary of the Ratka small water reservoir. The second point was set directly in the water reservoir. The last measuring point is located approximately 300 m under the water reservoir. The measurements were performed at monthly intervals in 2019. In order to ensure a higher level of accuracy, the field measurements were repeated three times. The measurements were carried out using the portable Pocket Pro + Multi 2 multimeter. The following characteristics of the surface water's quality were evaluated: the water temperature, pH reaction, salinity, and total amount of dissolved substances.


*Fig. 1.* Location of the Ratka water reservoir and sampling points (*Source*: sk.mapy.cz)

# 4. RESULTS

## 4.1. Hydrotechnical and geotechnical evaluation of the Ratka small water reservoir

One of the main elements of evaluating the landscape of a water reservoir includes the current state of the water body and its surroundings. Significant logging was identified as a long-term and persistent activity in the area under consideration. As a result, deterioration of the small water reservoir is expected in the coming years. The negative effects of the logging are increasing sediments, water pollution, and flood risks. The environment around the water reservoir is also polluted by waste, which impacts the quality of the water in a negative way.

***4.1.1. Crest.*** The body of the dam (Fig. 2a) is formed by a loose, homogeneous embankment that contains clay and sandy soils. The dam crest is reinforced by gravel, and the upstream side is formed by a stone plain. The windy slope is humified. The dam body should be maintained and machined every year. The responsible institution for the maintenance of the Ratka small water reservoir is the Municipal Office, which is located in the village of Ratka.

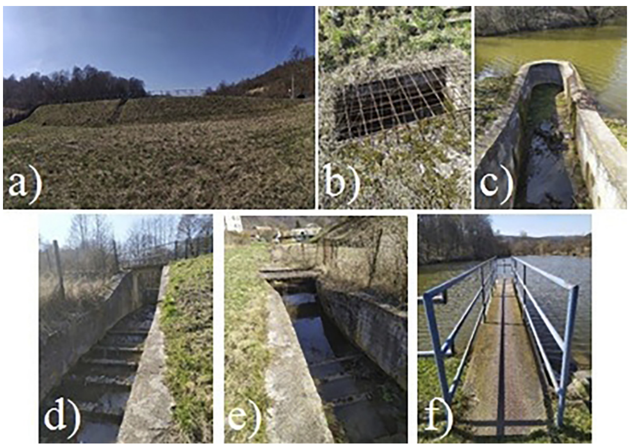


*Fig. 2.* a) Crest, b) operation shaft, c) spillway d) slip, e) stilling basin, f) footbridge

***4.1.2. Operation shaft.*** The operation shaft is shown in (Fig. 2b). It is obvious that its functioning and security is not satisfactory. The shaft is covered with a very poor quality iron grid and does not provide sufficient protection. The shaft is connected to the discharge structure below the minimum reservoir level.

***4.1.3. Spillway.*** The spillway (Fig. 2c) represents one of the most important elements of the design of the water structure with its main purpose being to protect the area under consideration before maximum peak flows [18]. A spillway is a safety measure against overtopping and failure. It is a permanent structure that must be regularly maintained, observed, and cleaned. During research on the spillway's terrain, significant contamination with biological material was found. Therefore, disinfection must be performed.

***4.1.4. Slip.*** The slip (Fig. 2d) is contaminated with sediments and deposits. It is assumed that it has not been cleaned for a long time; it is therefore highly recommended to perform maintenance and cleaning of the slip in order to restore its proper functionality.

***4.1.5. Stilling basin.*** The stilling basin (Fig. 2e) is a structure for damping the kinetic energy of the falling water and connecting waste from the drain to the riverbed under the dam. Based on the field measurements, it is highly recommended to clean the element of sediments and biological material.

***4.1.6. Footbridge.*** In 2008, the reconstruction of the footbridge was performed (Fig. 2f). The device for control and maintenance of the discharge structure is located on the footbridge. Since the reconstruction was carried out in 2008, no refurbishments are needed at this time.

## 4.2. Ecological evaluation of the Ratka small water reservoir

In order to evaluate the ecology of the Ratka small water reservoir, the quality of the surface water was measured and analyzed. This subsection contains the results of the field measurements for the selected water quality indicators, i.e., the water temperature, pH reaction, salinity, and total amount of solutes.

***4.2.1. Water temperature.*** The water temperature is one of the basic indicators of the quality of surface water, and other water quality indicators directly depend on it. With an increasing water temperature, chemical processes occur in water reservoirs that create negative impacts resulting in deterioration of the water quality. During the period evaluated, the average temperature of the water above the small water reservoir was 10.15 °C, 14.92 °C directly in the reservoir, and 14.26 °C on the bed of the reservoir. The minimal temperature of the water was recorded in December (2.77 °C), and the maximum water temperature was found in July with a value measured at 27.17 °C. The course of the water temperature is shown in Fig. 3.

The recommended value for the temperature of water according to Regulation of the Government of the Slovak Republic No. 269/2010 is <26 °C. Based on the measurements, 93% of the results analyzed meet the given requirement for the temperature of the water.

***4.2.2. pH reaction.*** The values of the pH reaction represent a significant element, which affects the chemistry of water directly as it relates to nitrification and impacts the life in the water as well. High values of a pH reaction are toxic for fish and plants living in the water. Therefore, it is important not only to monitor this value but also to keep it at the optimal level. Based on the measurements, the water in the reservoir belongs to the neutral and alkaline group of pH reactions.

The lowest pH value of the reaction occurred at the first sampling point in November. The highest pH value measured was recorded in August at the second sampling point with a value of 8.97 (Fig. 4).

According to Slovak Government Regulation No. 269/2010 [19], the recommended values should be in a range from 6–8.5. Based on the results, only 66% of the measurements meet the recommended values. Most of the results that do not meet the recommended values were taken from the second collection point, i.e., directly from the Ratka water reservoir.

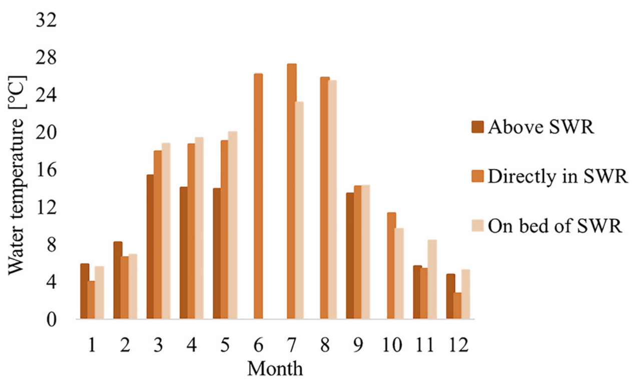


*Fig. 3.* The course of the water temperature during the analyzed period

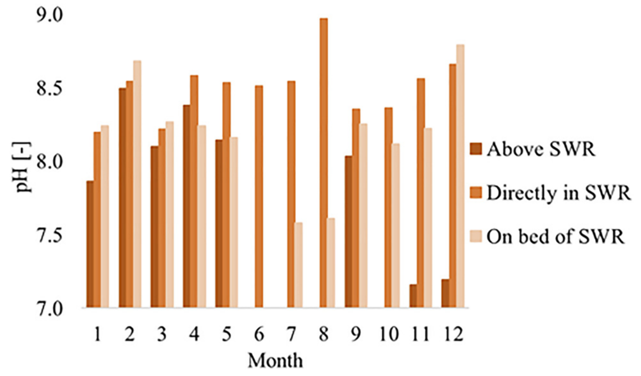


*Fig. 4.* The course of the pH reactions during the period analyzed

***4.2.3. Salinity.*** The lowest salinity values were found directly in the Ratka water reservoir (Fig. 5). The highest values were measured at the first sampling point (above the small water reservoir). Based on the results, it is clear that the water located in the water reservoir is considered as fresh water (fresh water is limited by salinity measured up to 0.50%). The measurements were taken in unit parts per trillion, which represent very small values when converted to percent values.

***4.2.4. Total dissolved solids.*** With an increasing water temperature, the total amounts of soluble solids increases. The highest values of Total Dissolved Solids (TDS) were recorded at the first sampling point in March with the value of 678 ppm. The lowest values of TDS were found at the second sampling point in January with a value of 279 ppm. Figure 6 represents the course of the total amounts of soluble solids during the analyzed period. According to the theoretical recommendations, the water in the Ratka water reservoir is considered as a mineral water with a high amount of minerals.

## 5. DISCUSSION

During the monitoring period no significant damage was observed at the Ratka small water reservoir that would have a major impact on its functionality and operability.

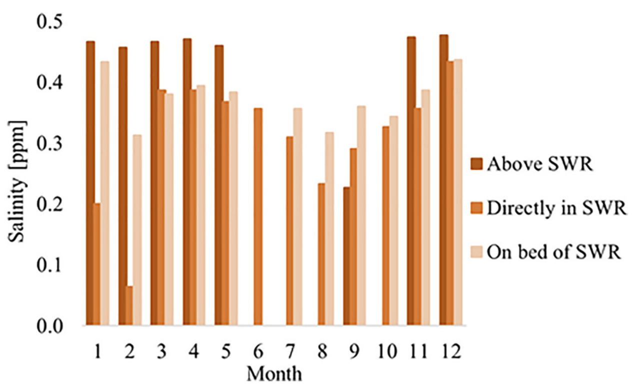


*Fig. 5.* The course of the salinity during the analyzed period

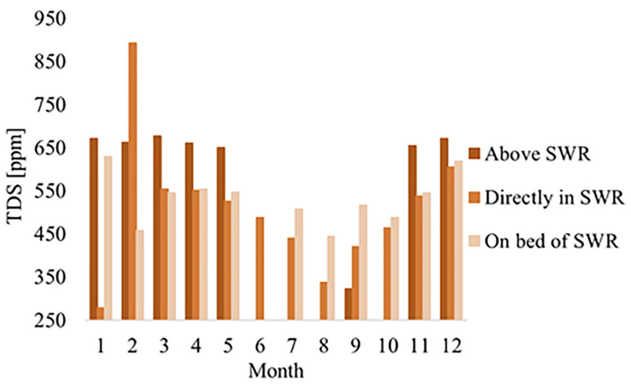


*Fig. 6.* The course of the TDS during the analyzed period

From a hydrological point of view, the period evaluated is classified as a very dry year. A lack of rainfall occurred in the months of June, July and October; during this time period it was not possible to perform field measurements due to the lack of water in the Cerová stream [20].

According to [21], five main impacts of a water reservoir on natural water bodies are specified, i.e., reduction of microhabitats, transport of sediments, changes in trophic potential, changes in the flow and temperature regime, and disruption of the aquatic animal migration. In addition, water bodies have the ability to affect the surrounding environment [22].

The Ratka small water reservoir is a water reservoir that is not well known and where no measurements have been undertaken to analyze the surface water quality. Since the measurements were performed only in 2019, it would be suitable to repeat the measurements in the future and thereby evaluate the changes that could occur in the quality of the surface water.

From an ecological point of view, the water quality in the Ratka water reservoir does not meet the recommended (limit) values of Government Regulation No. 269/2010 [19].

The second sampling point, which is located directly in the reservoir (increased water temperature, increased values of pH reaction) is in the worst condition.

It can be said that each water reservoir represents an important landscape element and a necessary part of the growth of the human population. Damming streams and rivers are one of the oldest human activities [23]; however, it is also a potential source of danger that can cause fatal damage [24]. Therefore, it is very important to pay attention to each water reservoir by maintaining it on a regular basis and assessing the environmental impact of water constructions [25].

## 6. CONCLUSION

Based on the results, it can be concluded that the Ratka small water reservoir represents a safe construction that is capable of performing the function for which it was designed. From a hydrotechnical and geotechnical point of view, several deficiencies were found, i.e., contamination of the spillway and slip and operating shaft with an unsuitable cover, and pollution of the environment around the water reservoir. The Ratka small water reservoir is a water reservoir that is not well known and where no measurements have been undertaken to analyze the surface water quality. Since the measurements were performed only in 2019, it would be suitable to repeat the measurements in the future and thereby evaluate the changes that could occur in the quality of the surface water.

## ACKNOWLEDGEMENTS

This study was supported by the Slovak Research and Development Agency under Contract No. APVV-15-0497 and VEGA Grant Agency No 1/0891/7. The authors thank the agencies for their research support.

## REFERENCES

[1] M. Hossain, “Water: The most precious resource of our life,” *Glob. J. Adv. Res.*, vol. 2, no. 9, pp. 1436–1445, 2015.

[2] G. L. Stephens, J. M. Slingo, E. Rignot, J. T. Reager, M. Z. Hakuba, P. J. Durack, J. Worden, and R. Rocca, “Earth’s water reservoirs in a changing climate,” *Proc. R. Soc. A, Math. Phys. Eng. Sci.*, vol. 476, no. 2236, Paper no. 0458, 2020.

[3] K. Kalúz, Š. Rehák, K. Hlavčová, and J. Szolgay, *Water Management of the Country* (in Slovak). Nitra: Slovak University of Agriculture in Nitra, 2010.

[4] D. Marcouiller and S. Coggins, “The economic value of water: An introduction,” in *Water Issues in Wisconsin*, Water as a Public Good: Property Rights. University of Wisconsin-Madison, 1999.

[5] Ľ. Jurík, E. Pierzgalski, and V. Hubačíková, *Water Structures in the Countryside, Small Water Reservoir* (in Slovak). Nitra: Slovak University of Agriculture in Nitra, 2011.

[6] H. Biemans, I. Haddeland, P. Kabat, F. Ludwig, R. Hutjes, J. Heinke, W. von Bloh, and D. Gerten, “Impact of reservoirs on 745 river discharge and irrigation water supply during the 20th century,” *Water Resour. Res.*, vol. 47, no. 3, Paper no. W03509, pp. 1–15, 2011.

[7] J. Downing, “Emerging global role of small lakes and ponds: Little things mean a lot,” *Limnetica,* vol. 29, no. 1, pp. 9–24, 2008.

[8] F. Habets, J. Molenat, N. Carluer, O. Douez, and D. Leenhardt, “The cumulative impacts of small reservoirs on hydrology: A review,” *Sci. Total Environ.*, vol. 643, pp. 850–867, 2018.

[9] N. M. Hayes, B. R. Deemer, J. R. Corman, N. R. Razavi, and K. E. Strock, “Key differences between lakes and reservoirs modify climate signals: A case for a new conceptual model,” *Limnol. Oceanogr. Lett.*, vol. 2, pp. 47–62. 2017.

[10] H. Horn, L. Paul, W. Horn, and T. Petzoldt, “Long-term trends in the diatom composition of the spring bloom of a German reservoir: is Aulacoseira subarctica favoured by warm winters?” *Freshw. Biol.*, vol. 56, no. 12, pp. 2483–2499, 2011.

[11] G. B. Sahoo, A. L. Forrest, S. G. Schladow, J. E. Reuter, R. Coats, and M. Dettinger, “Climate change impacts on lake thermal dynamics and ecosystem vulnerabilities,” *Limnol. Oceanogr.*, vol. 61, no. 2, pp. 496–507, 2016.

[12] M. Dokulil, “Old wine in new skins – Eutrophication reloaded: Global perspectives of potential amplification by climate warming, altered hydrological cycle and human interference,” in *Eutrophication*, A. Lambert and C. Roux, Eds., Ch. 3, 2014, pp. 95–125.

[13] I. J. Delpla, A. V. Baurès, E. Clement, and M. T. Olivier, “Impacts of climate change on surface water quality in relation to drinking water production,” *Environ. Int.*, vol. 35, pp. 1225–1233, 2009.

[14] B. Moss, S. Kosten, M. Meerhoff, R. W. Battarbee, E. Jeppesen, N. Mazzeo, K. Havens, G. Lacerot, Z. Liu, and L. De Meester, “Allied attack: climate change and eutrophication,” *Inland Waters*, vol. 1, no. 2, pp. 101–105, 2011.

[15] K. Krigovská, *Land Adjustment Program in the Cadastral Area Ratka* (in Slovak). Lučenec: Geodetic office, Eduard Gruy Ltd, 2012.

[16] Ministry of Environment Slovak Republic: Preliminary flood risk assessment in the sub-basin Ipľa – update 2018, Implementation of Directive 2007/60 /EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, pp. 1–14, 2018.

[17] *“Ratka Water Structure - Operation Regulations*. SPHI Lučenec: Slovak Water Management Company, OZ Banská Štiavnica, 2014.

[18] T. Stephens, *Manual on small earth dams; A guide to siting, design and construction*. Food and Agriculture Organization of the United Nations, Rome, 2010.

[19] *Government Regulation No. 269/2010*, Coll. Regulation of the Government of the Slovak Republic laying down requirements for achieving good water status, Slovak Republic, 2010.

[20] K. Jeneiová, L. Janečková, L. Blaškovičová, J. Podolinská, B. Síčová, and S. Liová, “Evaluation of the hydrological year 2019,” (in Slovak), *Vodohospodársky spravodajca*, vol. 3–4, pp. 20–24, 2020.

[21] N. L. Poff and D. D. Hart, “How dams vary and why it matters for the emerging science of dam removal,” *Biosci.*, vol. 52, pp. 659–668, 2009.

[22] M. S. Albdour and B. Baranyai, “Water body effect on microclimate in summertime: A case study from Pécs,” *Pollack Period.*, vol. 14, no. 3, pp. 131–140. 2019.

[23] P. Beracko, A. Rogánska, and T. Čejka, “Impact of small reservoirs on the community of the permanent component of macrozoobenthos of Small Carpathian streams,” (in Slovak), *Folia Faun. Slovaca*, vol. 17, no. 4, pp. 345–356, 2012.

[24] J. Pařílková, Z. Gardavská, M. Fejfarová, and Z. Zachoval, “Long-term monitoring of the earth dam by a small water reservoir method EIS,” (in Czech), *Acta Hydrol. Slovaca*, vol. 13, no. 1, pp. 90–100, 2012.

[25] M. Zeleňáková and L. Zvijáková, “Selection of impact indicators and their evaluation for environmental assessment of water construction,” *Pollack Period.*, vol. 6, no. 3, pp. 83–92, 2011.