

## VULNERABILITY AND PROTECTION OF THE WATER BODY "MODRAC"

Dinka Pasic-Skripic<sup>1</sup>, Mirna Asceric<sup>2</sup>

### INTRODUCTION

Hydroaccumulation Modrac was built in 1964 to provide technological water for the needs of industry, and today it also has a water supply role for the drinking water of Tuzla and Lukavac. Given that wastewater is discharged into waterways mostly without any remedial treatment, the water body "Modrac" is therefore continuously exposed to contamination by various harmful and dangerous pollutants.

Due to the complex geological and hydrogeological conditions in which the waters of the Modrac reservoir exist, as well as the great influence of anthropogenic pollution factors, the degree of vulnerability of these waters is significantly high. By defining the pollution cadastre, analyzing the degree of vulnerability, and assessing risk based on hazard and vulnerability, adequate prerequisites are created for the application of methods to protect the quality of these waters. This would ensure the preconditions for adequate protection of water quality, and improve the conditions for the use of these waters, especially in the sphere of water supply, given that these waters, along with previous treatment at the water factory in Cerik, are remedied and brought to the condition of drinking water, which must meet the regulations on the use of drinking water.

**Key words:** vulnerability of water, water body, pollutants, polluting substances

### 1. GENERAL CHARACTERISTICS OF THE "MODRAC" WATER BODY

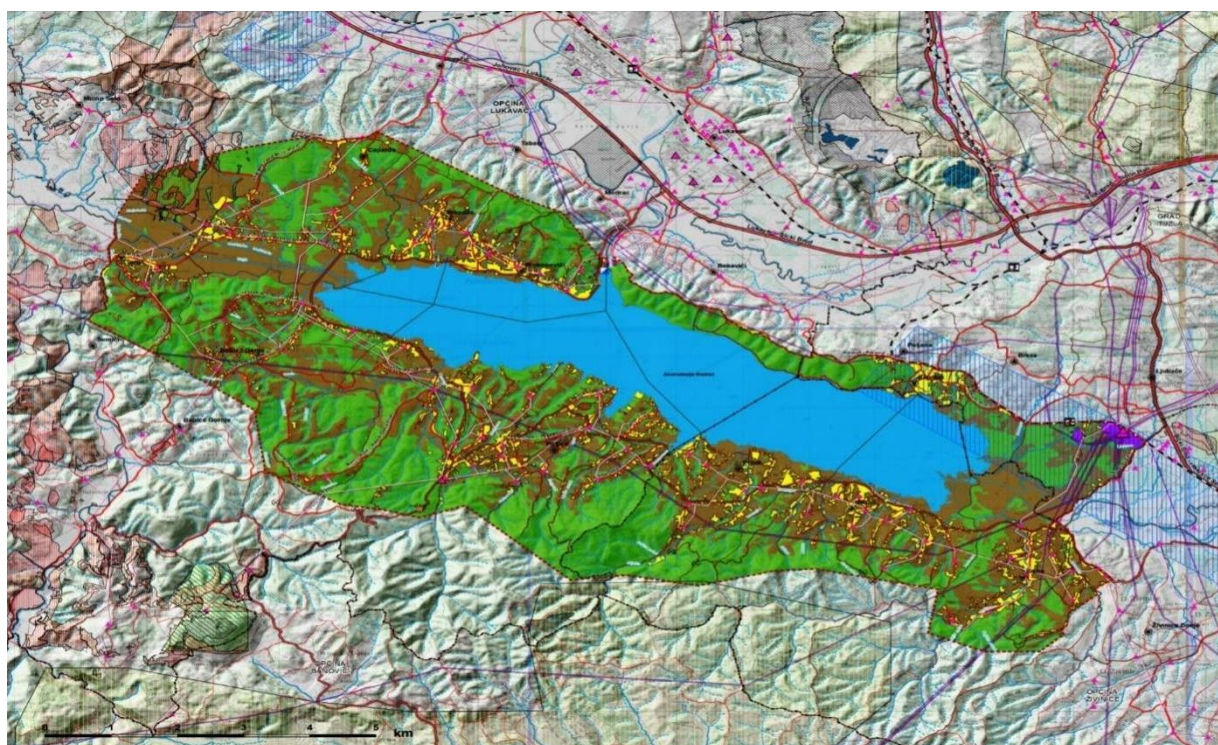
The catchment area of the Modrac reservoir is located in the central part of the Tuzla Canton, in the northeast of Bosnia and Herzegovina, covering an area of more than 1189 km<sup>2</sup>, which is administratively divided between the municipalities of Banovići, Živinice, Tuzla, Kalesija, Kladanj, Lukavac and Osmaci.

The water body has an area of 1673.98 ha, of which 30.00 ha or 1.8% of the total area belongs to the municipality of Tuzla, 35.8% to the area of municipality of Živinice, and 62.4% to the area of the municipality of Lukavac. Of the total area of the basin, which is 1189 km<sup>2</sup>, 832 km<sup>2</sup> belong to the Spreča river basin, 240 km<sup>2</sup> to the Turija basin, and about 117 km<sup>2</sup> to the immediate accumulation basin.

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<sup>1</sup>Ph.D., full-time professor at RGGF, Tuzla

<sup>2</sup> MA Civil Engineer



**Figure 1.** Map of the catchment area of the water body Modrac

## 2. CHARACTERISTICS OF THE CATCHMENT AREA

One of the very important factors in regulating the quantity and quality of water in the catchment area of the "Modrac" water body is the forest cover since it significantly affects the regime of both surface and underground waters. In the last ten years, the consequences of uncontrolled forest cutting could be noticed on the water body itself, in the form of frequent inflows of large waters and the deterioration of water quality.

The basin of the artificial lake Modrac is particularly interesting due to the protection of the lake from uncontrolled sediment and silt influx. Even before the construction of the Reservoir, significant erosion in the basin, production with transport of sediments into the artificial lake was predicted. Seen as a whole, the catchment area of the artificial lake Modrac has all the previous conditions for relatively sudden torrential inflows.

The average slope for the entire area is about 23%, with an average height difference of  $D = 211$  m, which indicates that the configuration of the terrain is moderately pronounced. Deep and surface erosion processes occur throughout the catchment area.

It is necessary to emphasize the following for the hydrological characteristics of the basin of the water body, which have a significant impact on the morphometric characteristics and water quality:

- The state of the water regime in the area of the Reservoir basin can be characterized by two elements: precipitation and water runoff. In the area of the basin, the average annual precipitation is about 1000 mm ( $l/m^2$ ), which is far less than the average for Bosnia and Herzegovina, which is 1250 mm;
- The specific runoff of water from the area of Tuzla Canton (of 12,50 l/s), indicates that this area is one of the poorest with water in Bosnia and Herzegovina;
- Although the basin of the Accumulation, on average, has relatively high precipitation, their variations in individual years, as well as within one hydrological year, are significant. The unevenness of water regimes of watercourses is characterized by the sudden arrival and short duration of large waters and the long duration of small and very small waters. That is why most

watercourses in the basin area have a torrential character, where the ratio of large and small waters is on average 1:1000;

Based on the above data, it can be concluded that in the catchment area of the "Modrac" water body, there are mostly watercourses with small water flows.

### 3. QUALITY OF WATER STREAMS

Inadequate attitude towards the problem of wastewater and preservation of water quality, above all surface water, has caused in the last 50 years a very complex situation in terms of pollution of surface (ground) water in the area of the entire basin of the "Modrac" water body. A sudden increase in wastewater, without adequate measures for its remediation, led to the direct discharge into surface waters, which changed the water quality of almost all watercourses in the Modrac reservoir basin.

According to the current legal regulations of Bosnia and Herzegovina, the Decree on the Categorization of Watercourses and the Decree on the Classification of Waters, all watercourses in the area of the Modrac reservoir basin are classified in the II category of watercourses, i.e. the II class of water quality.

When it comes to the state of surface water quality in the basin of the Modrac water body, by analyzing the results of the research, it can be concluded that the results of the latest research indicate that the water in the watercourses (Litva, Oskova, Gostelja, Spreča) is still of poor quality, in other words, worse than quality that is prescribed by law. Before a more detailed analysis of the water quality of the Modrac reservoir, it is necessary to bear in mind that the water body belongs to the river type of lake, which is unfavorable from the aspect of water quality maintenance, and that the reservoir has unfavorable morphometric characteristics, especially when it comes to the relationship between the surface and the depth of the reservoir. In addition to the above, the reservoir is supplied with water from the basin of a large area in which important commercial facilities are located, especially when it comes to coal exploitation (surface mines, pits, separations); the basin of the reservoir is poor in water, all watercourses in the basin have low water flows.

From the very formation of the reservoir until today, significant amounts of waste water, which are loaded with large amounts of various pollutants, especially suspended substances, are discharged into the waters of the watercourse in the basin of the reservoir continuously and without prior purification. Society as a whole, in the past 50 years, did not take appropriate measures to protect the "Modrac" water body, which in part affected the excessive endangerment of the reservoir, namely on two basic aspects: preserving the volume and preserving the water quality of the water body.

According to previous investigations of the state of water quality in the basin area of the Modrac water body, it is clear that the surface waters are excessively polluted and that the quality of the water, in the earlier period as well as today, is far worse than the quality defined by the Regulations on water classification and categorization of watercourses of BiH.

This situation is a consequence of the daily discharge of untreated municipal and industrial wastewater into the watercourses of the reservoir basin. Also, based on previous investigations of the state of the water quality of the Modrac reservoir, it can be concluded that there is a constant trend of deterioration, which is a consequence of the constant input of a significant load of pollution that occurs in the reservoir basin and is discharged into surface waters, mostly without purification, and tributaries (Spreča and Turija) enters the Modrac reservoir.

First of all, it should be emphasized that the introduction of suspended matter (as a consequence of mining activities in the basin) and nutrient substances (as a consequence of the discharge of sewage wastewater into the basin) is detrimental to the quality of the water of the reservoir. When it comes to surface water pollution in the reservoir basin, there is a significant number of scattered (diffuse) uncontrolled pollutants (rural settlements that do not have sewage systems, urban areas, roads, agricultural lands, etc.).

To gain insight into the problem of surface water pollution in the basin, as well as water pollution of the reservoir itself, pollutants are divided into municipal, industrial, and other. About 130,000 inhabitants live in the reservoir's catchment, whose wastewater without prior treatment ends up in the Modrac reservoir's catchment, and this specifically refers to the sewerage of municipal water in the settlements of Lukavac, Banovići, Tuzla, Živinice and Kalesija. According to the available data, 12 major industrial polluters and around 60 minor polluters are located in the catchment area of the reservoir.

The most significant are coal mines (surface mines and pits), Dubrave, Banovići, and Đurđevik; Coal mines (separation), Banovići and Đurđevik. The most significant other polluters include garbage and waste dumps located in the basin of the reservoir, as they pose a serious threat to its pollution.

#### 4. ASSESSMENT OF WATER VULNERABILITY

The Modrac reservoir was formed in 1964, with the primary purpose of providing industrial water for the economic capacities of Tuzla and Lukavac, as well as providing the water management (hydrobiological) minimum for diluting wastewater that is discharged into the river Spreča, downstream. Since the end of 2006, it has also been used to supply water to the population of Tuzla and Lukavac.

Vulnerability maps of underground and surface water represent the basis for the quality protection of these resources. They are an important factor in spatial planning so that construction does not cause negative impacts on groundwater quality. Therefore, they, along with other maps such as maps of potentially polluting substances of surface and underground water, help to identify possible risks.

Risk determination plays a significant role in the protection of underground and surface waters. Assessment of groundwater and surface water vulnerability to pollution varies in complexity, from simple and relatively inexpensive approaches, to rigorous quantitative and expensive assessments. By analyzing the negative impacts on the quality of surface and underground water, certain conclusions can be reached through the creation of a map of the vulnerability of the Tuzla Canton (Figure 2), which is of great importance for establishing the basis of quality protection of underground (surface) water.

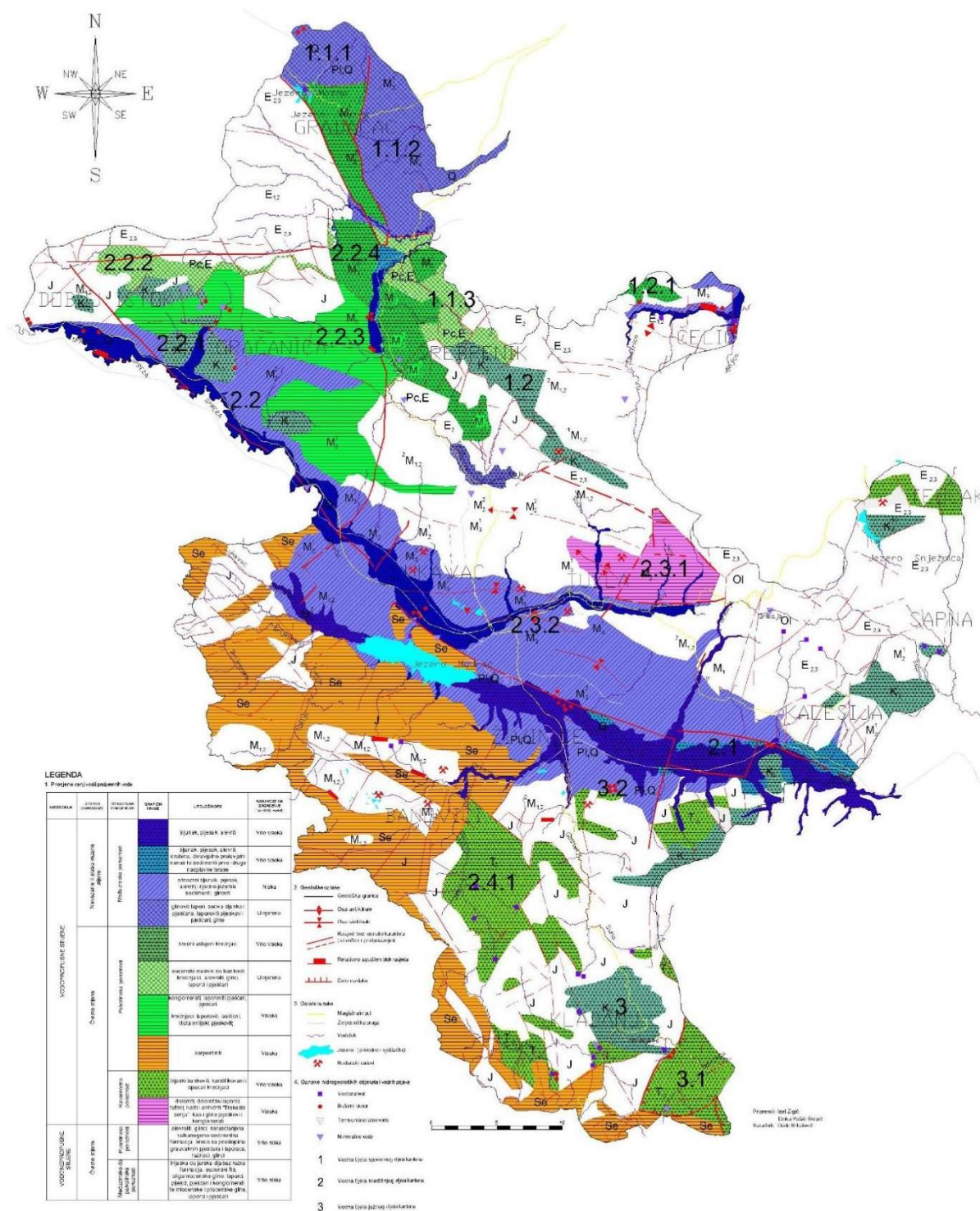
The sensitivity of an aquifer is a measure that shows the ease with which water enters the aquifer and moves through it, which is a characteristic of the aquifer itself covering sediments, i.e. overall hydrogeological conditions and is independent of the chemical characteristics of possible pollutants and sources of pollution. Aquifer characteristics include: filtration coefficient, porosity and hydraulic gradient, where it is important to know recharge conditions, relationships with surface water and movement through the overburden zone. The vulnerability of groundwater to pollution depends on the naturally existing sensitivity, as well as on the location of the type of source, natural or anthropogenic pollution, mass transport, and mass exchange of pollutants. In recent years, several methods have been developed that treat groundwater vulnerability, with different authors providing their definitions and understanding of the term "groundwater vulnerability".

The GOD method, which was used to create the vulnerability map of the Tuzla Canton (Figure 2), is a simpler version of the DRASTIC method, and as an index method, it includes the knowledge of three input values, namely: the circumstances in which groundwater exists, the overall lithology and the depth to the level of underground water.

The method was named after S. Foster and R. Hirata (1988), who patented it, and it stands for Groundwater occurrence – Overall lithology – Depth to groundwater. This method is suitable to be applied on maps at a scale of 1:100,000, which cover a fairly large area and include several influencing factors on water pollution.

In the GOD method, in the scheme of the indexing system for groundwater vulnerability, the starting point is the type and depth of groundwater, as well as the overall lithology of the permeable or semi-permeable formation, whereby vulnerability ratings are given in the step value gradation, from no to extreme vulnerability. The vulnerability of the "Modrac" water body, defined according to the GOD vulnerability method, indicates that the "Modrac" water body is classified as very vulnerable.





**Figure 2.** Vulnerability map of groundwater bodies of Tuzla Canton 1:100,000

## 5. PROTECTION OF WATER BODY MODRAC

The quality of water in the Modrac reservoir has been steadily deteriorating over the last four decades, as evidenced by continuous discharges of untreated wastewater from various sources of pollution, the largest of which are mine wastewater from separations, municipal water, and water from industrial plants. Little progress is evident in the goal of water protection of this watercourse, which is defined through the drafting of several laws on water protection and monitoring, but the laws are insufficiently applied, and monitoring is not aligned with needs and is not carried out continuously.

Regardless of the accumulated problems, in the water body and the area of the basin, biodiversity has been established that deserves European and world attention, especially since the construction of wastewater treatment plants in a wider area has recently started.

To stop the trend of water quality deterioration and improve the water quality of the water body "Modrac" and the environment, a more active coordinated joint action of the competent ministries, municipalities, as well as experts who will be able to recognize, first of all, the importance of this water body, not only from the aspect of industrial and drinking water needs but also as sport-recreational and sustainable biodiversity of wider significance, than the narrow perception of the reservoir as an exclusively hydro-technical object. It is necessary to urgently take appropriate measures at the sources of pollution to reduce (remediation) the introduction of polluting substances into surface waters, to start applying legal regulations, and to raise the awareness of all users of the water body about the necessity of its protection.

## CONCLUSION

The problem of pollution of underground and surface water and the geological environment, as well as their remediation, appears as an integral part of the overall problem of protection and preservation of the human environment. Their protection from pollution, as well as the protection of the environment in which they exist, is very complex, especially their remediation. The complexity of remediation can be seen in the fact that it is a multidisciplinary issue. Considering the complex geological and hydrogeological conditions in which the waters of the "Modrac" water body exist, as well as the great influence of natural and anthropogenic pollution factors, the degree of vulnerability of these waters is significantly high. By defining the pollution cadastre, analyzing the degree of vulnerability, and assessing risk based on hazard and vulnerability, adequate prerequisites are created for the application of methods to protect the quality of these waters. This would ensure the preconditions for adequate protection of water quality, and improve the conditions for the use of these waters, especially in the sphere of water supply, given that these waters, along with previous treatment at the water factory in Cerik, are remedied and brought to the condition of drinking water, which must meet the regulations on the use of drinking water.

The provision of all the aforementioned prerequisites results from adequate water remediation methodologies aligned with complex geological, hydrogeological, hydrological, and hydro-technical research, following adequate vulnerability maps, as well as the definition and establishment of high ecological standards in the researched area.

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