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APPLYING FORENSIC SKILLS TO DETERMINE THE ECOLOGICAL STATUS OR BIOTIC INDEX OF LAKE MAVROVO

Pollution of waters in current conditions presents serious environmental problem, not only in Republic of North Macedonia, but also in global frames, especially in conditions of limited approach to natural resourses. Water has significant part in creating healthy human environment. Republic of North Macedonia has average water wealth, and the spatial and temporal distribution is of vital importance and it is closely related to the annual and spatial distribution of precipitation. Therefore, surface waters represent enormous potential for the Republic of North Macedonia, however due to the lack of water in the Republic of North Macedonia, there are also several artificial water accumulations that are built on surface watercourses in order to meet various needs (irrigation, energy, water supply, etc.). Because of the numbers of penalties, crimes and misdemeanors of water pollution the legislator has to incriminate the behaviors that pollute the drinking water, water for livestock and irrigation etc. Environment forensic is significant element for detecting causers of polluted water, and the same presents the subject of interest for this scientific work. However, the author's performed forensic water expertise on Lake Mavrovo and thereby gave reference of the actual state of polluted water. These examinations were realized in order to prevent and suppress this phenomenon leading to the pollution of water in this region, positive practice which could be applied to the waters in other regions, as well. Examinations which were realized in order to define environment status of the lake, through determining biotic index and physicochemical parameters of water and, also expertise in the area of water pollution were performed.

***Keywords**: surface waters, pollution, expertise, biotic index, ecological status*

1. INTRODUCTION

More than two thirds or 70 percent of the Earth's surface is covered by water expanses. Water has universal significance for the whole living world. It is in the base of the physiological processes in living organisms, almost all biogeochemical processes are affected by the presence and its course, water is a primordial and current living medium. Despite its importance, today water or water surfaces are facing increased anthropogenic pressure that effects, with their increased spending on the one hand and pollution on the other hand, a process that not only limits their use value but has negative repercussion on biological components that inhabit them.

Pollution of water surfaces is a global problem that equally affects surface drinking water, surface waters – lakes, rivers and oceans, but also the groundwater. In order to stop further degrading anthropogenic effect on water surfaces, and even more, to take action to improve the conditions to the extent that would be close to the situation with very small or no anthropogenic pressure, in 2000, the European Union promoted and put into effect the European Water Directive. It should serve as a framework for water management and protection, uniformed throughout the European Union, and generally on the territory of whole Europe. Deadline which is defined for achieving the main goal of this Directive which is "good ecological status" is 2015 (Directive 2000/60/EC, 2000: 72).

European Water Directive allows harmonization of legislation for the water protection and management and it should be implemented in all EU member states. Candidate countries also need to harmonize the national legislation according to the principles of the European Water Directive. From this perspective, the Republic of North Macedonia as a candidate country for EU membership is also obliged to coordinate its own legislation with the European Directive regulation and to implement the requirements contained therein. To protect the waters in the Republic of North Macedonia in 2008, the Law on Water was adopted (Official Gazette of the Republic of Macedonia, no. 87/2008). This law implemented international legal acts, i.e. directives for water protection.

This paper analyzes the situation regarding water pollution of Mavrovo Lake, through the application of forensic methods of research in order to define the ecological status of the lake, by monitoring the biological and physicochemical parameters of water, and also expert report was given in the field of water pollution.

2. ECOLOGICAL STATUS TERM AND DEFINITION

The European Water Directive (Directive 2000/60/EC, 2000) is the framework for measures and also for the protection of European water resources such as: inland surface waters, trans-boundary waters, coastal and ground water. The Directive seeks to enable the development of mechanisms that will help prevent further degradation as well as to improve the status of aquatic ecosystems, integrally with the protection of terrestrial ecosystems.

The directive could be considered an "amalgam" of existing water protection measures and activities introduced into the EU Member States since the early 1970s (Latifi, 2011: 5).

The lack of a joint European Water Platform, or the existence of much different legislation on protection and management with water in Europe, is the basic premise for the establishment of the European Water Directive (Irvine, 2004: 107–112). The same applies to the protection and, in cases where is necessary, and also to the improvement of the status of inland and groundwater by implementing the model for integrated river basin management.

The main objective of the European Water Directive was to achieve "good ecological status" and "good chemical status on surface water" for all surface water within year 2015. According to Article 4, for artificial and modified water surfaces, the term "good ecological potential" was introduced, which was also objective to be reached within the 2015 timeframe.

The terms surface water status, ecological status and ecological potential are defined in the Directive in the following way:

Surface water status - Article 2 reflects the status of surface water, which is below the quality of environmental and chemical status.

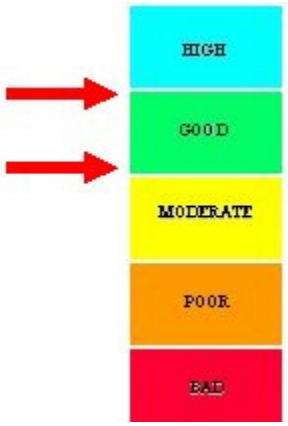
Ecological status - Article 2 relates to the quality of the structure and functionality of the aquatic ecosystem of surface water, classified in accordance with Annex V.

A good ecological potential Article 2 is the status for artificial water surfaces and modified water surfaces in agreement with the relevant measures of Annex V.

In the classification scheme of the European Water Directive, water quality is defined by 5 classes of statuses: high, good, moderate, weak and poor (Figure 1).

High status refers to the status of surface water, when there is little or no anthropogenic pressure on the biological, chemical and morphological components

Figure 1: Color classification scheme for colossal status of porcine waters under the Water Directive (Latifi, 2011: 6)



of the aquatic ecosystem. This status is also referred to as a "benchmark", because it is the most well-meaning status that can be achieved. However, this status or reference conditions are specific to different types of water surface and correlate with the diversity of ecological regions in Europe.

The rest of the status classes are based on deviations from the reference state, or conditions, in the following way: good status indicates a situation where it has a slight deviation from the reference conditions.

The general definition of a lake in good ecological status or potential under the "General Conditions" is: *"Temperature, oxygen balance, pH, acid-neutral capacity, transparency and salinity should not have values beyond the limits determined to enable the functioning of specific ecosystem types and the achievement of values specified for biological quality elements. Nutrient concentrations do not cross their boundaries to enable the specific ecosystems to function."*

Moderate status means the state of anthropogenic influence of moderate character relative to the reference status; poor status indicates a strong anthropogenic pressure and changes in the aquatic ecosystem, while poor ecological status is associated with the most obvious changes in the conditions relative to the reference state.

The assessment of the status as to the potential surface water bodies is based on the qualitative elements contained in Annex V of the Water Directive.

The lists of these qualitative elements for each category of surface water are divided into three groups of "elements":
1. Biological elements
2. Hydromorphological elements, in function of biological elements
3. Physico-chemical elements.

3. FORENSIC ASPECTS OF THE STUDY OF THE WATER IN LAKE MAVROVO

Veen-excavator with a capacity of 400 cm^2 is used while exploring the waters in Mavrovo Lake and collecting the material for quantitative research (Figure 2).

Figure 2: Van Veen - excavator (Latifi, 2011: 29)

Other tools were also used for sifting the material, collected in glass jars previously labeled with the date and place. Namely, the collected material was fixed with a usage of 96% ethyl alcohol and transported to the laboratory where the determination of macrozoobenthos was performed (Figure 3).

Figure 3: Part of the equipment used during the laboratory work (Latifi, 2011: 29)

Sample collection for analysis was within quarterly dynamics relative to the middle of each one-year seasons. The probes were collected by transect route and 5 GPS transects were identified and selected in such a way as to enable comparability of the data according to the criteria of the Water Directive, and should reflect the natural state of the lake or these profiles are located along the littoral part of the lake when there is no anthropogenic pressure at all.

Field activities:

- Following on the qualitative composition of the communities of macrozoobenthos that inhabit the bottom of Moors Lake. These qualitative analyzes make it possible to draw up a list of species recorded in the different survey periods of the five profiles.

- Following on the quantitative composition of the benthic fauna that is, following the changes in the numerous compositions of the macrozoobenthos communities.
- Follow-up of the qualitative and quantitative composition of the benthic fauna as a function of: time of research (seasonal changes); the depth and texture of the bottom, that is, the facies of the lake.

Figure 4: Explored profiles in Mavrovo Lake (photo by Google Earth) (Latifi, 2011: 35)

Laboratory activities:

- Determination of the Biotic Index (BI) for quantification of the ecological status of the Lake in accordance with the Water Directive.
- Determination of the structural indices of communities from macrozoobenthos in different habitats.

In order to quantify the level of pollution or to determine the ecological status of the lake, metrics data or information for the benthic fauna were used through the Biotic Index. The biotic index was introduced by William M. Beck (Solimini et al., 2006: 48) as a tool, that is, a scale over which the quality of the aquatic environment under test is displayed. The values on this index range are from 1 to 10, and correspond to the four basic levels (statuses) for water quality.

Biotic index formula:

$$BI = \frac{\sum xiti}{n}$$

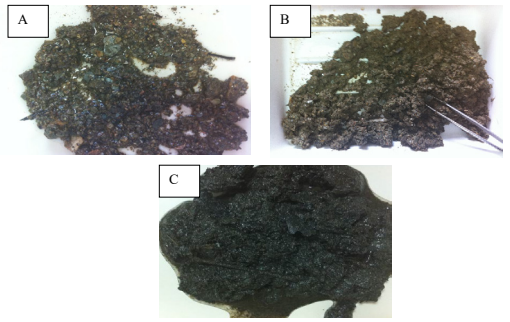
Where:

xi = number of individuals of the species given
ti= tolerance value
n = total number of organisms in the trial

4. RESEARCH AND DISCUSSION

The analyzes of sediments from the bottom of the lake, which were not investigated for their own sake, but investigated as a function of exploration for benthic fauna, show that the facies of the bottom are represented by three main types of sediments.

Figure 5: The three basic types of facies at the bottom in Moors Lake: A-RS (Rocky-sandy substrate); B-S (Sandblasting substrate); C-SL (sludge lining) (Latifi, 2011: 43)



The representatives of macrozoobenthos in Mavrovo Lake, found on the 5 profiles and by depth separatly, are analyzed from several aspects, and they are determined by their qualitative and quantitative composition, as well as their horizontal and vertical distribution. In addition, the qualitative and quantitative composition was investigated and followed by the time of the survey (seasonal changes); the depth and texture of the bottom or the facies of the lake.

Determination of macrozoobenthos representatives was performed at the Bental Fauna Laboratory at the Hydrobiology Institute of Ohrid.

During the period 2010/2011, the following representatives of the eccentric fauna were recorded in the extant profiles on the Mavrovo Lake.

Class Oligochaeta

Order Haplotaxida
Fam. Tubificidae
Tubifex tubifex
Limnodrilus hoffmeisteri
Limnodrilus udekamianus
Class Insecta
Order Diptera
Fam. Chironomidae
Procladius choreus
Polypedilum sp.
Chironomus plumosus
Chironomus thummi
Chironomus sp.
Cricotopus sp.
Order Odonata
Fam. Aeshnidae
Aeshna grandis
Fam. Gomphidae
Gomphus vulgatissimus

The list contains a total of 11 taxa from 4 families belonging to 2 classes: Oligochaeta and Insecta recorded in Moors Lake.

Of the 11 species identified, the largest number of species is represented by the Chironomidae family (6 species), followed by the Tubificidae family (with 2 species). Families Aeshnidae and Gomphidae are represented by only 1 species each.

Figure 6: Total number of species identified from macrozoobenthos by sites in Mavrovo Lake during 2010/2011 in explored profiles (Figure 4). (Latifi, 2011: 67)

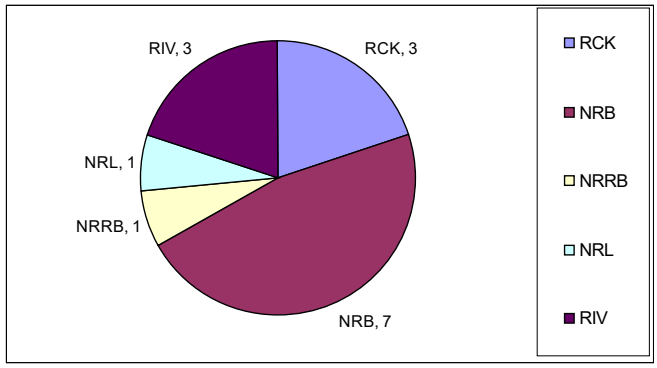
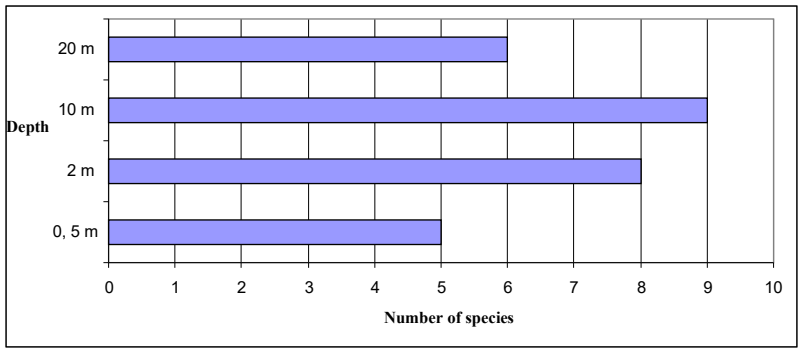


Figure 7 gives an overview of the vertical distribution, that is, the qualitative composition with respect to the depths tested. It is seen that there is a gradient in the type of distribution that is inversely proportional to the increase in depth. Thus, at a depth from 0.5 m only 5 species are registered, at 2m 8 species and at 10m the largest number of species is registered, which is 9. At the largest

depths the species composition is reduced again.

Figure 7: Number of species of macrozoobenthos by depth in Mavrovo Lake (Latifi, 2011: 69)



Benthic macroinvertebrates are used in lake classification (Wiederholm, 1981: 140–141; Kansanen, Aho and Paasivirta, 1984: 55–76; Aagaard, 1986) and represent indicators of lake quality, owing to their sensitivity or tolerance to different types of pollution (Johnson Wiederholm and Rosenberg, 1993: 488; Bazzanti, Seminara and Baldoni, 1998, 405–412).

$$BI = \frac{\sum xiti}{n}$$

xi = number of individuals of the species given

ti= tolerance value

n = total number of organisms in the trial

Figure 8: Values of the Biotic Index of different localities in Mavrovo Lake (Latifi, 2011: 85)

5. CONCLUSION

Environmental forensics is part of the criminalistic techniques, specifically its discipline that develops and applies knowledge, methods and means of detection, investigation and clarification of the disturbance of the environment. In order to determine the current status of all ecosystems, including water and water resources, it is necessary to perform situational expert in the field in order to prove the pollution of water and detect causes of pollution.

According to sediments, i.e. facies at the bottom, in the Mavrovo Lake, from the aspect of distribution and diversity of the benthic fauna, it was determined

the existence of three basic types of facies: rocky-sandy bottom; Sandblast and sludge lining bottom.

Macrophytic vegetation is not present in Mavrovo Lake, a fact that is conveniently reflected in the qualitative composition, distribution and density of benthic fauna, other aquatic organisms, and generally the trophy of the entire ecosystem.

The list of recorded species of benthic fauna is poor and contains a total of 11 taxons from 4 families belonging to 2 classes: *Oligochaeta* and *Insecta*. The largest number of species is from the family *Chironomidae* (6 species), *Gomphidae* and *Aeshnidae* are represented by only 1 species each.

The highest number of species was recorded in the NRB locality, while in the two localities it was registered identically, or the smallest number of species, one species each. The species distribution exhibits an atypical depth gradient, that is, to a certain depth the diversity increases and then decreases.

Explored Profiles	*Value*	*Value of BI*	*Water quality according BI*		*Water Directive*
NRRB 6.00 RCK 4,50 NRL 8.00 RIV 8,68 NRB 9,16		0.00-3.50	Excellent		High
		3.51-4.50	Very good		
		4.51-5.50	Good		Good
		5.51-6.50	Moderate		Moderate
		6.51-7.50	Moderate poor		Poor
		7.51-8.50	Bad		Bad
		8.50-10.00	Very bad		

The biotic index in the RCK profile has values that indicate good ecological status. The values of Biotic Index in the NRRB profile are within the limits of moderate ecological status, while the values of Biotic Index in the other three profiles indicate poor ecological status and presence of organic pollutants.

The general conclusion is that forensic skills “In Situ” on the surface water can provide us biotic index results which gives us accurate data on the ecological status of surface water and the type of pollutants.

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ПРИМЕНА НА ФОРЕНЗИЧКИ ВЕШТИНИ ЗА УТВРДУВАЊЕ НА ЕКОЛОШКИОТ СТАТУС И БИОТИЧКИОТ ИНДЕКС НА МАВРОВСКОТО ЕЗЕРО

Загадувањето на водите во моменталните услови претставува сериозен проблем за животната средина, не само во Република Северна Македонија, туку и во глоални рамки, особено поради ограниченият пристап до природни ресурси. Водата има значајна улога во создавањето на здрава животна средина. Република Северна Македонија има просечно богатство со вода, а просторната и временската распределба на водата е од витално значење и е тесно поврзана со годишната и просторна распределба на врнежите. Затоа, површинските води претставуваат огромен потенцијал за Република Северна Македонија, но поради недостатокот на вода во Република Северна Македонија, има и неколку вештачки акумулации на вода што се градат од површински водотеци со цел да се задоволат различните потреби (наводнување, енергија, водоснабдување и сл.). Поради бројните прекршоци, дела и злоупотреби од аспект на загадување на водата, Законодавецот би требало да го инкриминира поведението на загадување на водата за пиење, водата за добиток, водата за наводнување и сл. Еколошката криминалистика претставува значаен елемент во детекцијата на загадените води и истовремено претставува предмет на интерес на овој научен труд. Авторите на овој труд извршија експертиза на водите во Мавровското Езеро и притоа дадоа одредени референци за моменталната состојба со загадувањето на водата. Ваквите испитувања беа реализирани со цел да го превенираат и спречат феноменот на загадувањето на водата во овој регион, како и за утврдување на позитивни практики кои можат да се применат на водите во другите региони. Испитувањата беа реализирани со цел да се дефинира еколошкиот статус на езерото преку утврдување на биотички индекс и физичко-хемиски параметри, како и експертиза на областа каде што е утврдено загадувањето на водите.

***Клучни зборови**: површински води, загадување, експетиза, биотички индекс, еколошки статус*