International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 6 Issue 1||January 2017 || PP. 19-23

Assessment of The Trophic Status of The Future Buk Bijela HPP Accumulation

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Abstract: *Eutrophication is a natural process in which water bodies age, and transit from a low productive condition (oligotrophic) into a high productive condition (eutrophic). In such condition, a majority of organic substances that are produced in surface layers do not completely decompose, but settle on the bottom, where they decompose. An increased (artificial) input of nutrients significantly accelerates this process, disturbing the natural balance between the biomass production and mineralization, where the production considerably multiplies. This can lead to a successful decrease in oxygen concentration on the bottom of an eutrophic lake, and in more inconvenient cases even to an anaerobic condition. This can result in an increase in the concentrations of ammonium, iron, manganese, and other substances, as well as in the occurrence of hydrogen sulphide and methane, which has a negative impact on the quality, both from the aspect of biotope habitat and water usage possibilities.*
Keywords: *Eutrophication, accumulation, hydro power plant, Buk Bijela*

I. Introduction

Artificial accumulations are generally built for several purposes, for the needs of different users. Negative effects of eutrophication mostly reflect on the possibilities to use this water for water supply and recreational sports activities[1]. Elementary purpose of the planned HPP cascade is energy production, where this potentially generates possibilities to use the formed backwater to improve the existing, and develop new touristic sports activities in this area. In these terms, development of eutrophication processes can have several key effects on the possibilities to use the accumulation for recreation and sport:

- development of macrophytes in littoral zones of accumulations, which has a negative effect on access possibilities;
- decreasing water transparency due to an intensive growth of algae;
- intensive growth of algae can lead to the accumulation of biomass in some zones of the accumulation with decreased water circulation[2].

On one hand, this has negative aesthetic consequences, and on the other it can lead to stench in the vicinity. Also, eutrophication development has a negative impact on the possibilities of using this water for sports or commercial fishing. Although eutrophication entails an increased production of ichthyofauna, present fish species change, from the noble species to the species that are not noble. This paper has assessed the possibilities of eutrophication incidence in the future Buk Bijela HPP accumulation[3].

II. Description Of The Project And Location

Buk Bijela hydro power plant is planned for construction in the upper Drina river course, in the territory of the municipality of Foča in southeast Bosnia and Herzegovina. The Drina River is a right and largest tributary of the river Sava and belongs to the Black Sea watershed. It is generated by a merger of the rivers Tara and Piva near Šćepan Polje. Its basin covers an area of 19 570 km^2. The Drina river, together with the Tara is about 500 km long, and the Drina alone about 341 km, with an average width of the basin of 100 km. Average flow of the Drina near Šćepan polje is about 150 m^3/s, and at the confluence of the Drina and the Sava about 400 m^3/s. The Drina river basin represents the most significant unused hydro-potential in the Balkans.

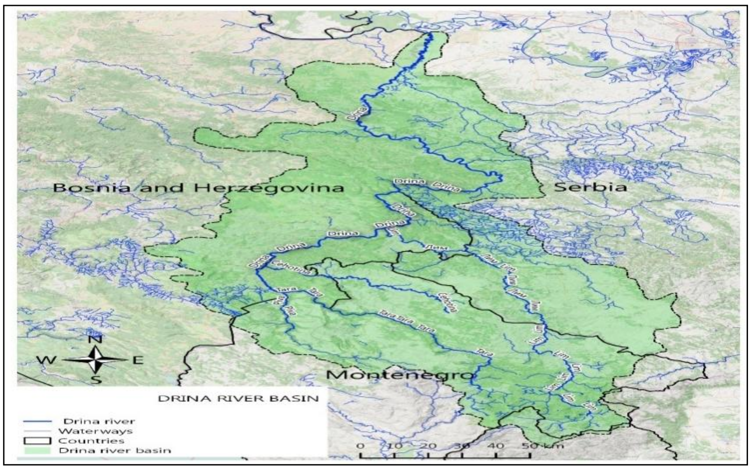

Figure 1 Drina River basin

A gravitational concrete dam with the crown elevation of 436.20 masl was planned for construction in the upper Drina river course. The width of the dam in its crown is changeable, and ranges from 9.85 to 15.50 m. Its construction will form an accumulation with an elevation of the normal backwater of 434 masl, and a total volume of 15.70 mil.m^3. The dam consists of the spillway and non-spillway section, with a total length in the crown of 197.30 m. Non-spill section on the left bank has total lengths of 68.20 m and 33.50 m on the left and right banks, respectively.

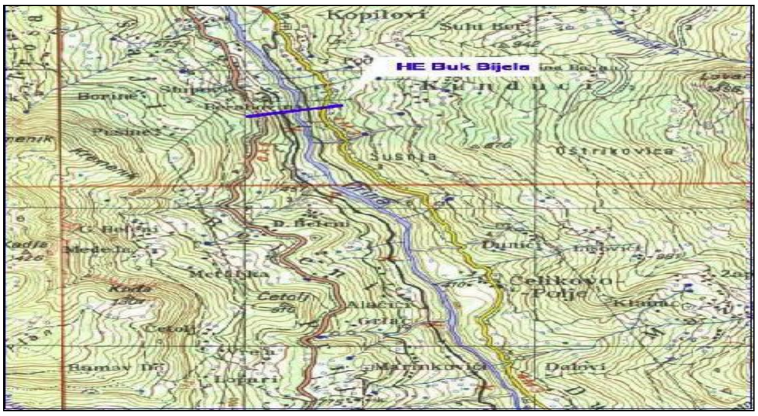

Figure 2 Micro location

Table 1 Basic data on the project size

No.	Position	Buk Bijela dam and accumulation 433.6 masl
I	Technical parameters	
I 1.	Chainage (km)	334+550
I 2.	levation of normal backwater (masl)	434
I 3.	Elevation of maximal level (masl)	434
I 4.	Expropriation elevation (masl)	437.0
I 5.	Accumulation length (km)	11.50
I 6.	otal volume of the accumulation (10^6 m^3)	15.70
I 7.	Usable volume (10^6 m^3)	11.0
I 8.	Volume of dead space (10^6 m^3)	4.70
I 9.	Inundation area (ha)	163.30
I 10.	Area under the riverbed (ha)	52.85
I 11.	Number of aggregates	2+1
I 12.	Installed flow m^3/s	150 + 150 + 50 = 350
I 13.	Type of turbine	Kaplan
I 14.	Installed power MW	2x40.11 + 1 x 13.3 = 93.52

III. Methods of the implemented assessment

When analysing data that are used for the elaboration of an impact analysis, it is possible to apply two basic approaches.The first is to define adequate models of newly constructed structures, in this case an accumulation, or a new water body. This requires a large number of measurements on the locations where a new structure will be constructed. Then, it is necessary to know the profiles, their applications and a series of bathymetric parameters. After an accumulation is constructed, the measurement of its properties, both hydrological and chemical, and biological can generate an adequate monitoring model[4].

Second approach is to observe a newly generated structure and its interaction with the surroundings, as a dynamic system, where the effects are observed through a selection of indicators. The essence of such approach is to observe a lake as a water body that shows its environmental impact through the indicators, in this case nutrients; it is to say production of nitrogen, ammonium and phosphorus in the water body and environment.

This approach requires a smaller amount of input data. In the case of the construction of a hydropower plant on the river Drina, the first approach is inapplicable in this phase because there are lots of parameters that are not known at this moment.

The second approach is applicable because it does not depend on accumulation hydro-parameters. It is clear that this approach provides no unambiguous model of accumulation's behaviour from the aspect of water quality, but it clearly describes the conditions that will be generated after a period, which can be used to analyse accumulation's fate in the future. Also, what is more significant is that the changes in nutrient presence are forecasted in adequate time periods.

Assessment of the trophic status in the future accumulation

4.1. Nutrients

Primary production, as well as the first and basic element in the process of eutrophication, is conditioned by available quantities of nutrients in the water, primarily nitrogen, phosphorus and carbon. Thereby, the presence of two mentioned elements is considered a limiting factor.

Nitrogen represents a significant element in the production of algal biomass, it is to say in the generation of elementary cell mass[5]. Besides, it plays a significant role in the form of a regulator of diverse biochemical processes. Elementary sources of increased nitrogen concentrations in the water represent used waste water from the settlements, as well as diverse agricultural and industrial activities. Based on the available data on the water quality for the period 2007-2009, it can be stated that the average value of contents of different forms of nitrogen ($NH4+$, $NO2-$, $NO3-$) amounts to about 1.13 mg/l in the profile immediately downstream from the Ćehotina confluence.

Phosphorus represents a key element in the process of photosynthesis, and usually represents a limiting factor of primary production. It is considered that the limit value of concentration of available phosphorus for the efficient photosynthesis is about 0.01 mg/l. Found average value of orthophosphates in the river Drina, in the Foča profile, is 0.0125 mg/L, whereas the concentrations of total phosphorus are about 0.24 mg/L.

Relation of average annual values of contents of nitrogen and phosphorus approximately amounts to 50, which entails that phosphorus would be an extremely limiting nutrient in possible process of eutrophication. This can imply compulsory measures of protection in the phase of exploitation of the planned accumulation in terms of preventive measures for discharging phosphorous substances into the river, such as control and treatment of used waters, or control of erosion processes.

On the other hand, it is known that phosphorous compounds are prone to adsorption on solid particles of deposits. Deposition of suspended deposits is expected after the accumulation is formed; this would result in capture of available phosphorus on the bottom and significantly lower concentrations of dissolved phosphorus compounds. Foreign examples show that up to 80% of the introduced phosphorus is accumulated in the sediments in natural processes. Phosphorus in the sediments can be reactivated under the circumstances of oxygen deficit on the bottom, which cannot be expected in the case of subject accumulation, given the nature of run-of-river hydroelectric power plant and short period of water retention in the accumulation.

The following table shows the properties of the planned accumulation and assessed average period of water retention in the warmest part of the year (July-September).

Table 2 Averagetime of retaining water in the accumulation during the warm (vegetation) part of the year (July-September)

Barrier	F (km^2)*	V x 10^6(m^3)*	Qsr (m^3/s) annual	Qsr (m^3/s)**	T (days) *
Buk Bijela HPP	1.21	15.7	162.4	65.12	2.8

**At the elevation of normal backwater*

***In the period July-September*

4.2. Status assessment

In the case of the construction of hydro power plants on the river Drina, the first approach (described in the methods) is inapplicable in this phase because there are lots of parameters that are not known at this moment. Second approach is applicable because it does not depend on hydro parameters of the accumulation. It is clear that this approach provides no unambiguous model of the accumulation's behaviour from the aspect of water quality, but it clearly describes the conditions that will be generated after a period, which can be used to analyse accumulation's fate in the future. Also, what is more significant is that the changes in nutrient presence are forecasted in adequate time periods[6].

When analysing the behaviour of accumulations, water basins, it is elementary to identify conditions in which eutrophication can start. Such analysis is made based on the forecasts of changes in elementary nutrients, phosphorus, nitrogen and ammonium, during a period of time.

The analysis is based on input data on measurements of water quality performed in the vicinity of locations, it is to say on the principal watercourse, where elementary Biochemical Oxygen Demand (BOD5), chemical oxygen demand (COD) and chlorophyll are measured. Balance of the mentioned elements is made based on these measurements with certain assumptions, such as a number of water changes in the accumulation, water temperature and quantity of dissolved oxygen. It is assumed that the level of nutrients in the accumulation ensues from the environment, then from the watercourse and discharge from deposited sediments in the accumulation itself.

This analysis used a balance model of principal nutrients; it is to say indicators of eutrophication process in accumulations. For example, changes in concentrations of total phosphorus are determined based on the following differential equation:

$$\frac{dP}{dT} = UP - IP$$

where P represents a concentration of total phosphorus, t denotes time, UP denotes all processes that represent an original member in the phosphorus balance, whereas IP represents processes that have an influence on the decrease of dissolved phosphorus in the accumulation.

Measured concentrations of phosphorus and nitrogen in the Drina river water in Foča, represent input for the model of changes in concentrations in the future accumulation.

For modelling, i.e. analysis of impacts of a number of water changes in the accumulation, were also used the measured values of biochemical oxygen demand (BOD5) in Foča, where a condition was set that the values of BOD5 stay in the limits of dissipation of the measured values.

The model assumed that water is changed 10 times on average during a month, which is an utterly "pessimistic" scenario, bearing in mind the data provided in Table 2.

Key element is phosphorus; an as low concentration as 0.01 mg/L is considered a limit for the commencement of eutrophication processes. Simulation for 10 changes during a month acquired the values of phosphorus concentration, which will be at a threshold where eutrophication starts (0.016 mg/L), which is in the limits of the existing condition in considered profiles.

IV. Discussion

Modelling, it is to say simulation, has shown, based on the starting measuring parameters and adopted assumptions of the worst-case scenario, that quantities of generated nitrogen will not be sufficient for commencement of eutrophication processes in the Buk Bijela accumulation.

Notably, according to the "pessimistic" scenario, 5 years after the beginning of accumulation forming, nitrogen concentration in the water can be expected at a level of about 0.15 mg/L.

Share of ammonium in the lake in the first five years of accumulation declines, hence there will not be generated conditions that are required for eutrophication commencement; this also entails a decrease in water quality, both in the accumulation itself and downstream. A problem that occurs is the assessment of sediments quantity that will generate after the dam is constructed. Regardless of the quantity, according to the simulation, the accumulation will not significantly be loaded, and water quality will not be affected in the lower Drina course, in a period of five years after the dam construction.

The formed accumulation is expected to be mesotrophic, it is to say that values of Carlson's index (1977) (Carlson's Trophic State Index - TSI [1]) range between 45 and 50, in the following 10 years after the accumulation formation. In the same period, the number of phytoplankton should not exceed 6,000 units/ml, whereas biomass is assessed not to exceed 5,000 μg/l, so that environmental potential would by satisfactory.

V. Conclusion

General conclusion is that the trophic level for the planned accumulation directly depends on management method, i.e. measures that will be applied with the aim of reducing input of nutrients and organic pollution in the system[7].

Changed hydrological conditions frequently lead to an increased activity of some of the factors that influence the process of eutrophication, or the system's capacity of autopurification may decline. This accelerates the process. Changed regime of transfer of sediments and precipitation can affect the generation of macrophytes.

An increased production of phytoplankton can significantly accelerate the process of eutrophication. Hence it is necessary to have an influence on the intake of nutrients and organic pollutions in sectors in the accumulation zone, as well as in water bodies located downstream from the accumulation zone[8].

Due to a short retention of water in accumulations and presence of permanent circulation, there are no conditions for thermic stratification of water and possible intensification of eutrophication processes that would lead to anoxic conditions on the bottom of the accumulation. Of course, entire surface below adequate elevations will be prepared in terms of the removal of vegetation and surface soil layer before the formation of the accumulation.

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