Assessment of Tismana Downstream Storage Reservoir Ecological Potential by Water Quality Monitoring

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The study aims to assess the ecological potential of the Tismana Downstream Storage Reservoir on the basis of physico-chemical water quality parameters monitored in 2014-2015. Sampling has been performed in sections located in the middle and in the storage dam in March, June and October in order to determine the ecological state of the Tismana Downstream Storage Reservoir. Environmental status assessment was based on the values obtained for quality indicators monitored and by applying methodologies for assessment under the Water Framework Directive 60/2000/EC. The ecological status was determined by the worst indicator. The followings physico-chemical quality elements such as lake acidification status, dissolved oxygen, chemical oxygen (COD-Cr), biochemical oxygen demand (BOD_5) and nutrients regime have been monitored. The monitoring results showed that, in terms of the general physical-chemical indicators, Tismana Downstream Storage Reservoir has good ecological potential.

Key words: storage reservoir, monitoring, physico-chemical parameters, ecological potential

Lakes are important water bodies in preserving freshwater and replenishing underground water. They have an important role in adjusting local climate and ameliorating environment, consequently, they are considered one of the most versatile ecosystems in the world [1]. The physical and chemical properties with hydro-morphological situation of the lakes and biological characterization are used to determine the ecological status of them [2]. This is important due to the fact that according to Water Framework Directive all the member states of European Union are obliged to assess and to report the ecological status of water bodies in lakes exceeding a surface are 0.5 km^2 [3-5]. The ecological status is determined by biological, chemical and physical characteristics of the water bodies and their variation from reference cases [6]. According to Royal Haskoning for UKTAG [6] the ecological potential of a water body represents the degree to which the quality of the water body's aquatic ecosystem approaches the maximum it could achieve, given the heavily modified and artificial characteristics of the water body that are necessary for the use or for the protection of the wider environment [7].

Planning of water resources in oder to recover their hydropower potential represents an area with wide implications in terms of the influence on water quality. Storage reservoirs accomplishment is a brutal intervention in the balance of natural ecosystems which consequences must to be estimated, prevented and controlled, so in parallel with meeting of technical criteria for which was designed the storage to also ensure the ecological, aesthetic and social conditions. Lakes formed by artificial retaining of water show changes of water quality indicators due to stall of water for a while in lake reservoir, air temperature and thermal stratification phenomena (summer and winter). Their composition is generally heavily influenced by biological phenomena due to sludge settling in much larger quantities [8-10]. The large volume of water, generally provides a constant composition, greater variations being caused by streams, by stirring the surface, and in certain periods by the development (at increased intensities of solar radiation) of green algae. Thermal stratification combined with mineral stratification in case of deep lakes determines during summer and autumn to the exclusion of vertical water circulation. This thing triggers the decreasing of dissolved oxygen concentration in bottom area and anaerobic oxidation processes appearance having as effect the increasing of organic substances, nitrogen and phosphorous salts content, and sometimes hydrogen sulphide occurence on the lake bottom.

The effects of the storage reservoir to the water quality depend largely on geographical position, on the mode of operation of the dam, and the level of industrialization and agricultural development in that hydrographic reservoir. One storage reservoir influences water quality in each phase of implementation (filling operation).

The graph of exploiting reservoirs lead to changes in thermal stratification and distribution of dissolved oxygen, which also changes the chemical properties of water and sediments. In extreme cases, the presence and operation of reservoirs can accelerate the rate of aging of the water body and its eutrophication, affecting its different uses. The development of algae and other aquatic plants leads to accumulation of plant biomass and detritus, generally resulting in a degradation of water quality.

Filling the lake and increasing the water stagnation time in the lake changes the content of nutrients in the water, and its degree of mineralization. These phenomena also tend to stabilize over a long period of time on the dam operation. The main sources of nutrients and degree of mineralization of water in the reservoirs come from stream flows. Usually, achieving one hydrological planning is accompanied by increasing of urbanization, industrial and agricultural activities in the upstream, which means increasing amounts of domestic, industrial, and agricultural waste that are typically taken by waterways.

Experimental part

Tismana Downstream Storage Reservoir is schemed on Tismana river being situated on mountain area at an altitude of 210 m above sea level, it has an average depth of 16 m, and an area of 0.21 km^2. The dam is formed of

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reinforced concrete and it has a length of 137 m, a width of 6 m and a height of 10 m. The retention time is small (<3 days). The storage reservoir is a part of the hydropower systemTismana Tismana Downstream and is framed in the typology ROLA08. The water's dam is used to produce electricity and water supply.

Sampling was performed for analysis of physico-chemical elements, in March, June and October on the sections located between the dam and storage reservoir to assess its ecological potential. Physico-chemical indicators determined are: the state of acidification (pH), level of oxygen (oxygen dissolved in terms of concentration, COD-Cr, BOD_5) and nutrients ($N\text{-}NH_4^+$, $N\text{-}NO_2^-$, $N\text{-}NO_3^-$, N_{total}, $P\text{-}PO_4^{3-}$, P_{total}).

For sampling from lakes, and for analyzing the physical and chemical water indicators the standardized methods and techniques were used. Sampling points were set to be representative samples for physico-chemical water quality. Acidification status was measured electrochemical using a portable pH meter. Nutrients content was determined using standardized methods with UV-Vis spectrophotometer - T70. Nitrate content was determined by spectrophotometric method with 2,6-dimethylphenol by measuring the absorbance of reaction product at 324 nm wavelength. Determination of nitrite content in water samples was based on their reaction with 4-amino benzene sulfonamide reagent in the presence of phosphoric acid at *p*H 1.9. The resulting diazonium salt leads to a red colored complex with N-(1-naphthyl-ethylene diamine dihydrochloride) whose absorbance is measured at 540 nm. Ammonium content in water was determined by spectrometric measurement at 650 nm of a blue compound obtained by the reaction of ammonia with salicylate and hypochlorite ions in the presence of sodium nitroprusside. For the determination of different phosphorus compounds from the water reservoir (P-phosphate and P-total) we applied European standards using ammonium molybdate spectrometric method. The oxygen indicators were measured by volumetric methods as is required by standard analysis and water quality control.

Results and discussions

The values recorded in the period 2014-2015 for the two monitoring sections of the reservoir of Tismana Downstream Storage Reservoir are presented in tables 1-4.

Table 1

VALUES REGISTERED IN 2014 IN SAMPLING SECTION *MIDDLE* – S1 OF TISMANA DOWNSTREAM STORAGE RESERVOIR

No.	Indicator	M.U.	Values registered in March 2014	Values registered in June 2014	Values registered in October 2014
1	pH	pH units	7.42	6.70	7.00
2	Dissolved oxygen	mg O_2/L	11.2	10.1	10.0
3	COD-Cr	mg O_2/L	7.98	6.84	7.44
4	BOD_5	mg O_2/L	2.3	2.6	2.3
5	$N\text{-}NH_4^+$	mg N/L	0.034	<0.018	0.022
6	$N\text{-}NO_2^-$	mg N/L	0.006	<0.002	<0.002
7	$N\text{-}NO_3^-$	mg N/L	0.64	0.39	0.39
8	N_{tot}	mg N/L	< 2.93 (LD)*	< 2.93 (LD)*	< 2.93 (LD)*
9	$P\text{ - }PO_4^{3-}$	mg P/L	0.014	0.012	0.015
10	P_{tot}	mg P/L	0.017	0.019	0.019

*LD - Limit detection

Table 2

VALUES REGISTERED IN 2014 IN SAMPLING SECTION *DAM* – S2 OF TISMANA DOWNSTREAM STORAGE RESERVOIR

No.	Indicator	M.U.	Values registered in March 2014	Values registered in June 2014	Values registered in October 2014
1	pH	pH units	7.38	6.86	7.03
2	Dissolved oxygen	mg O_2/L	11.6	10.2	9.9
3	COD-Cr	mg O_2/L	7.53	6.24	8.06
4	BOD_5	mg O_2/L	2.8	2.4	2.5
5	$N\text{-}NH_4^+$	mg N/L	0.033	<0.018	0.023
6	$N\text{-}NO_2^-$	mg N/L	0.006	<0.002	<0.002
7	$N\text{-}NO_3^-$	mg N/L	0.66	0.38	0.41
8	N_{tot}	mg N/L	< 2.93 (LD)*	< 2.93 (LD)*	< 2.93 (LD)*
9	$P\text{ - }PO_4^{3-}$	mg P/L	0.016	0.012	0.014
10	P_{tot}	mg P/L	0.02	0.02	0.016

*LD - Limit detection

Table 3
VALUES REGISTERED IN 2015 IN SAMPLING SECTION *MIDDL* – S1 OF TISMANA DOWNSTREAM STORAGE RESERVOIR

No.	Indicator	M.U.	Values registered in March 2014	Values registered in June 2014	Values registered in October 2014
1	pH	pH units	7.40	7.17	7.33
2	Dissolved oxygen	mg O_2/L	12.14	10.42	11.17
3	COD-Cr	mg O_2/L	7.53	6.20	6.90
4	BOD_5	mg O_2/L	3.0	2.5	2.8
5	N-NH_4^+	mg N/L	0.032	<0.018	<0.018
6	N-NO_2^-	mg N/L	<0.002	<0.002	<0.002
7	N-NO_3^-	mg N/L	0.39	0.35	0.38
8	N_{tot}	mg N/L	0.52	0.43	0.48
9	P - PO_4^{3-}	mg P/L	0.015	0.019	0.021
10	P_{tot}	mg P/L	0.019	0.021	0.029

Table 4
VALUES REGISTERED IN 2015 IN SAMPLING SECTION *DAM* – S2 OF TISMANA DOWNSTREAM STORAGE RESERVOIR

No.	Indicator	M.U.	Values registered in March 2014	Values registered in June 2014	Values registered in October 2014
1	pH	pH units	7.12	7.21	7.19
2	Dissolved oxygen	mg O_2/L	12.64	10.28	11.70
3	COD-Cr	mg O_2/L	7.48	6.82	6.28
4	BOD_5	mg O_2/L	2.4	2.6	2.1
5	N-NH_4^+	mg N/L	0.022	<0.018	<0.002
6	N-NO_2^-	mg N/L	0.002	<0.002	0.002
7	N-NO_3^-	mg N/L	0.49	0.34	0.38
8	N_{tot}	mg N/L	0.56	0.40	0.60
9	P - PO_4^{3-}	mg P/L	0.011	0.020	0.009
10	P_{tot}	mg P/L	0.015	0.022	0.012

Graphical representations of the evolution of values in the period 2014-2015 in relation to limit values between ecological potential *Maximum* and *Good* (MEP/GEP) and *Good* and *Moderate* (GEP/MoEP) for indicators of oxygen regime and nutrients that are used for assessing the ecological potential of Tismana Downstream Storage Reservoir are shown in figures 1-6.

For the assessment of general physico-chemical quality parameters of Tismana Downstream Storage Reservoir we applied for all indicators monitored, the arithmetic mean for the season growth of phytoplankton from March to October, ecological status being given by *the worst indicator.*

The assessment of physic-chemical parameters of Tismana Downstream Storage Reservoir in the period 2014-2015, by calculating the average values of monitored indicators is as follows:

pH parameter

For storage reservoirs, the compliance with maximum ecological potential (MEP), good (GEP) and/or moderate (MoEP) in case of pH indicator will be as follows:

- If the arithmetic average of pH for phytoplankton growth season (March to October) is within the range 6.5 to 8.5, then the storage reservoir is considered as maximum ecological potential (MEP).
- If the arithmetic average of *p*H for phytoplankton growth season (March to October) is outside the range 6.5 to 8.5, then the storage reservoir has moderate ecological potential (MoEP).

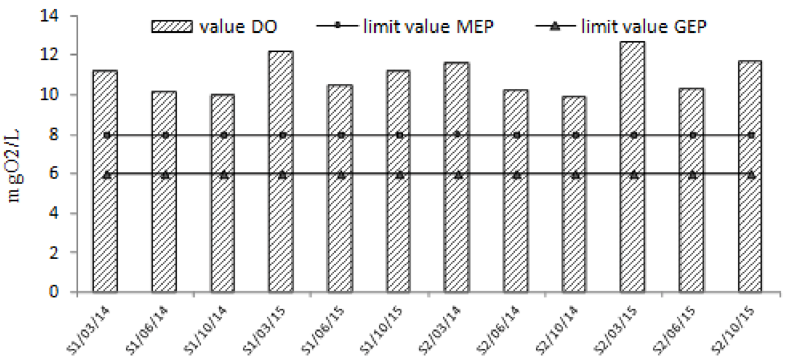

Fig.1. Variation of dissolved oxygen (DO) for Tismana Downstream Storage Reservoir (2014-2015)

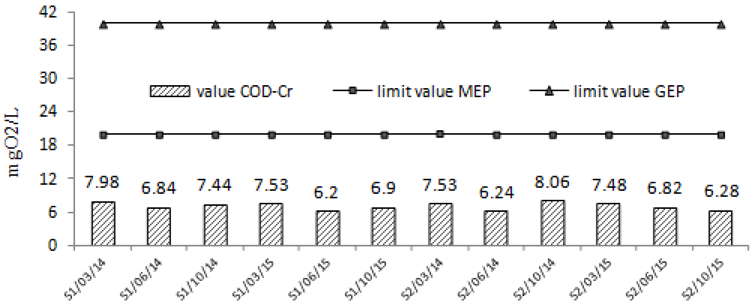

Fig. 2. Variation of COD-Cr for Tismana Downstream Storage Reservoir (2014-2015)

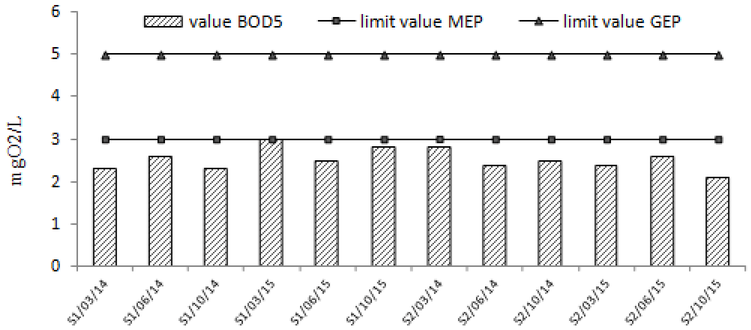

Fig.3. Variation of BOD_5 for Tismana Downstream Storage Reservoir (2014-2015)

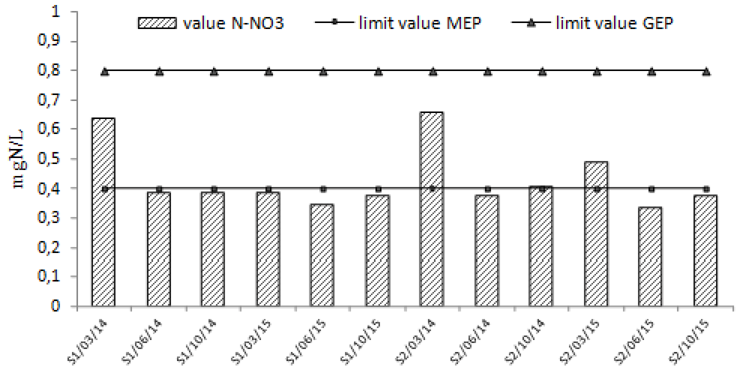

Fig.4. Variation of $N\text{-}NO_3^-$ for Tismana Downstream Storage Reservoir (2014-2015)

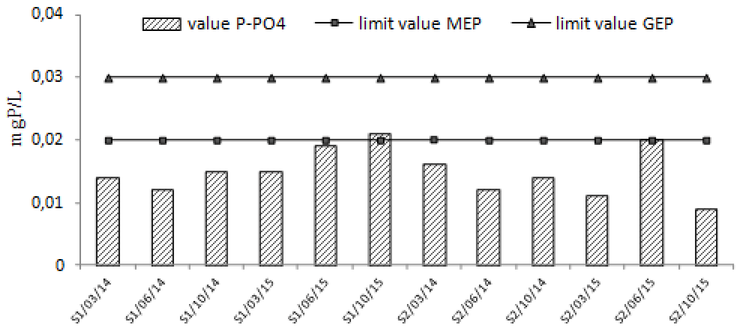

Fig.5. Variation of $P - PO_4^{3-}$ for Tismana Downstream Storage Reservoir (2014-2015)

The mean value of *p*H indicator for Tismana Downstream Storage Reservoir in the period 2014-2015, was 7.15 *p*H units. This value is characteristic for maximum ecological potential (MEP).

Oxygenation conditions

Since 2011, for the assessment of ecological potential of heavily modified water bodies - lakes, besides dissolved oxygen, BOD_5 and COD-Cr are used. Table 5 shows the limit values between ecological potential *Maxim* and *Good* (MEP/GEP) and *good* and *moderate* (GEP/MoEP) for reservoirs in typology ROLA08, a category that is included Tismana Downstream Storage Reservoir for indicators: BOD_5, COD-Cr and dissolved oxygen.

Average values of oxygen regime indicators for Tismana Downstream Storage Reservoir in the period 2014-2015 were as follows:

- dissolved oxygen: 10.945 mg O_2/L, the value characteristic for maximum ecological potential (MEP);

- chemical oxygen demand (COD): 7.108 mg O_2/L, the value characteristic for maximum ecological potential (MEP);

- biochemical oxygen demand (BOD_5): 2.525 mg O_2/L, the value characteristic for maximum ecological potential (MEP).

Nutrients regime

In terms of nutrients content, since 2011 in assessing the ecological potential of water bodies heavily modified such as lakes, besides P_{total}, $N\text{-}NH_4^+$, $N\text{-}NO_2^-$, $N\text{-}NO_3^-$, N_{total} and $P\text{-}PO_4^{3-}$ are used. The proposed values as boundaries between *Maximum* ecological potential and *Good* ecological potential (MEP/GEP) and *Good*" and *Moderate* (GEP/MoEP) for the nutrient indicators that are used for assessment of the potential ecological reservoirs are shown in table 6.

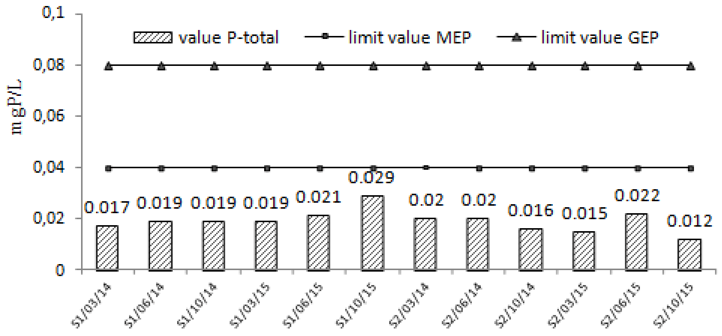

Fig.6. Variation of P_{total} for Tismana Downstream Storage Reservoir (2014-2015)

Table5

THE LIMIT VALUES IN ASSESSING THE ECOLOGICAL POTENTIAL OF RESERVOIRS FOR OXYGEN REGIME INDICATORS

Typological category	BOD_5 (mg O_2/L)		COD-Cr (mg O_2/L)		Dissolved oxygen (mg O_2/L)	
	MEP	GEP	MEP	GEP	MEP	GEP
ROLA08	3.00	5.00	20.00	40.00	8.00	6.00

Table 6

THE LIMIT VALUES IN ASSESSING THE ECOLOGICAL POTENTIAL OF RESERVOIRS FOR NUTRIENTS

Typological category	$N-NH_4^+$ (mg N/L)		$N-NO_2^-$ (mg N/L)		$N-NO_3^-$ (mg N/L)		N_{total} (mgN/L)		$P-PO_4^{3-}$ (mgP/L)		P_{total} (mgP/L)	
	MEP	GEP	MEP	GEP	MEP	GEP	MEP	GEP	MEP	GEP	MEP	GEP
ROLA08	0.20	0.40	0.00	0.35	0.40	0.80	1.00	2.00	0.02	0.03	0.04	0.08

The average values of indicators regarding nutrient regime for Tismana Downstream in the period 2014-2015 were as follows:

- the average value for $N-NH_4^+$ is 0,028 mg/L; this value is characteristic for maximum ecological potential (MEP);
- the average value for total nitrogen is 0.498 mg/L; this value is characteristic for maximum ecological potential (MEP);
- the average value for $N-NO_2^-$ is 0.004 mg/L being characteristic for good ecological potential (GEP);
- the average value for $N-NO_3^-$ is 0.433 mg/L; the value is specific for good ecological potential (GEP);
- the average value for $P-PO_4^{3-}$ is 0.014 mg/L, value being characteristic for maximum ecological potential (MEP);
- the average value for total phosphorus: 0.019 mg/L; this value is characteristic for maximum ecological potential (MEP).

The monitoring results for Tismana Downstream Storage Reservoir showed that *p*H indicators, DO, COD-Cr, BOD_5, $N-NH_4^+$, N_{total}, $P-PO_4^{3-}$ and P_{total} were fitted with the maximum ecological potential, and indicators $N-NO_2^-$ and $N-NO_3^-$ were fitted with the good ecological potential.

Ecological status is given by *the worst indicator*, thus it can conclude that, in terms of general physical-chemical indicators, Tismana Downstream Storage Reservoir has good ecological potential.

Conclusions

The purpose of this work was to evaluate the ecological potential of the Tismana Downstream Storage Reservoir by monitoring physico-chemical elements of water quality in period 2014-2015. In this sense, the methodologies for assessment under the Water Framework Directive 60/2000 / EC, which establishes and regulates the type of indicators monitored limit values were applied. The monitoring was conducted in March-June-October, by analyzing samples taken from two sections of the reservoir considered representative by point of view of the physico-chemical. They were namely middle and dam sections. Physico-chemical properties evaluated were acidification status, dissolved oxygen, chemical oxygen demand (COD-Cr), biochemical oxygen demand (BOD_5) and indicators for nutrient regime such as the content of $N-NH_4^+$, N_{total}, N-nitrite, N-nitrate, P-phosphate and P_{total}. From these ten indicators monitored, two were fitted with good ecological potential characteristic values, namely N-nitrite and nitrate-N. The values of other indicators analyzed in the period 2014-2015 were characteristic for maximum ecological potential. Thus, after monitoring, the ecological status of Tismana Downstream Storage Reservoir was determined by the worst indicator.

The monitoring results showed that, in terms of general physical-chemical indicators, Tismana Downstream Storage Reservoir has good ecological potential.

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