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Evaluation of Water Quality in Bovilla Reservoir Using Physico-Chemical Parameters during 2006-2008#

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Abstract: Bovilla reservoir was constructed in 1998 and is located about 15 km North-East of Tirana city. This reservoir is the main source of drinking water for the city of Tirana (more than 700.000 inhabitants). The aim of the study was to collect sufficient baseline quality data to provide a basis for future water quality protection and monitoring in Bovilla reservoir. Water quality samples were collected from May 2006 to May 2008 with a frequency of two months in three sites, in different depth of the lake (1m, 3m, 5m, 10m, 15m, 20m, 30m, 40m). Vertical profiles for water temperature, pH, dissolved oxygen (DO), conductivity, alkalinity, total phosphorus (TP), nitrite, nitrate, ammonium, total dissolved solids (TSS), turbidity, UV absorbance, BOD5, chlorophyll a, b, c and Secchi disk transparency were recorded. The study was carried on within the framework of SCOPES Program (Scientific Cooperation between Eastern Europe and Switzerland), project JRPIB 7320-111032/1 focused on "*Limnologic and hydrologic assessment of Bovilla basin (Tirana, Albania) and its watershed, focused on drinking water use*".

Keywords: *reservoir, drinking water, physico-chemical parameters, SCOPES project.*

Introduction

Bovilla watershed extends in the Eastern to Northeastern side of the capital, Tirana. The reservoir has a surface of 4575 km^2, maximum volume of 80 x 10^6 m^3, and average depth of 18 m. Residence time of the water is 4.23 years. It drains an area of approximately 98 km^2; the main source is river Tërkuza with total discharge about 105 x 10^6 m^3/year. The relief of the region is mainly hilly to mountainous, mountains mainly in the periphery (Kabo 1990)**.** Bovilla territory belongs to subhilly Mediterranean climate, with heavy precipitations (1200-1300 mm/yr), mainly during the end of the winter and end of the autumn. Average temperatures oscillate: min 7.6, max 18.2 and average 12.9 ºC.

Figure 1: Watershed of Buvilla basin with three sampling stations (S1-S3) (Image © Terremetrics, Europa Technologies and DigitalGlobe, from GoogleEarth*)*

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The water of this reservoir is treated by Treatment Plant of Bovilla, with a capacity up to 1800 l/s, through standard treatment: pre-disinfection, coagulation, clarifloculation, decantation, filtration, post-disinfestations; in case of extreme emergency a powdered activated carbon at clarifloculation step, is added, using a PAD Dosing System with a silo storage. The study was initiated in response to concern over the deteriorating water quality manifesting by an unpleasant smell and taste first detected on September 2001. After the 1st year of monitoring only station 1 was used for sampling because no significant differences between the three sampling stations were observed.

Materials and Methods

In-field measurements were: temperature profile, pH, conductivity, Secchi disk and turbulence using Multi-Parameter Meter HACH 54650-18. Parameters measured in laboratory were the following: dissolved oxygen, alkalinity, $KMnO_4$ Index, UV-A, total suspended solids (TSS), nutrients (P-PO_4^{3-}, N-NO_2^-, N-NO_3^-, N-NH_4^+) and chlorophylls.

A known volume of water (2-2.5 liters) has been filtered directly in the field using vacuum pump through a Whatman GF/C glass-fibre filter (0.45 μm pore size) for the measurement of pigments. Filters were frozen (-20^{0}C) until extraction with acetone. Additionally 1 liter of water sample was taken for other analysis. Water samples has been stored at -20^0 C or preserved/or not with sulfuric acid till pH≤1 according storage protocols (Henriksen, 1969; Gardolinski *et al* 2001).

For the determination of nutrients, UV-A, TOC and chlorophylls spectrophotometer UV-VIS, SHIMAZDU 2401 was used, while for the determination of total phosphorus was used spectrophotometer UV-VIS Pye-UNICAM SP-5 (measurement at 880nm).

Chemical parameters were determined according to APHA (1998) and EN/ISO ISO 6878, standard methods for water analysis.

Results and Discussions

Some parameters analyzed will be discussed here to evaluate the water quality of Bovilla reservoir according the norms of EC Environmental Directive 440 of 16/06/1975, *"Quality of surface water intended for the abstraction of drinking water"*.

Temperature measurements: Temperature changes are the cause of thermal stratification and overturn. During this two years period has been observed only two lake overturns, first on January 2007 and the second on November 2007 - January 2008 when the resistance to mixing is removed (temperature differences between layers resulted zero) and entire lake freely circulates. The spring (summer) overturns were not observed due the fact that winter temperatures in this area are not so low to form an colder (more dense) upper layer than the deeper layers. This phenomena is not unusual for moderately deep lakes situated in relatively cooler climates that are not covered by ice in winter. In such a case lake may have one long mixing period that lasts from fall into the following spring/early summer and a stratification period during summer (Horne et al 1994; Brönmark et al 2005).

Vertical thermal stratification was fully developed on July 2006 and 2007, when temperature differences between the two layers are about 19 degrees. Because the layers don't mix, they develop different physical and chemical characteristics, particularly dissolved oxygen concentrations but also other parameters. Some classical thermal situations happened during this period are presented in Figure 2: three summer stratifications (on July 2006, July 2007 and May 2008) and two winter overturns (both on January).

Surface temperature in Bovilla reservoir varied by 19.6 degree over the entire study period, while temperature at depth 40-45 m varied by 4.4 degree. A maximum surface water temperature of 27.2 ^oC was measured on July 2007 and a minimum temperature of 7.6 ^oC on January 2008; in deep waters a minimum temperature of 6.8 ^oC was found on March 2007 while the maximum temperature 11.2 ^0C was measured on November 2007. The most obvious reason for temperature change in Bovilla reservoir is the change in seasonal air temperature.

According EC Environmental Directive 440, guide level of temperature is 22 ^0C and mandatory level is 25 ^0C (in exceptional climatic or geographical conditions). The water sucked for the treatment plant (usually from the depth of 10-15 m) comply with this norms.

Dissolved Oxygen Concentrations: The amount of oxygen in the water is an important indicator of overall lake health. It is interesting to notice the variation of DO concentration during the months presented in Figure 3. Cyclic changes are seen, showing the highest levels in periods from January to May and the lowest levels during hot season and immediately after it.

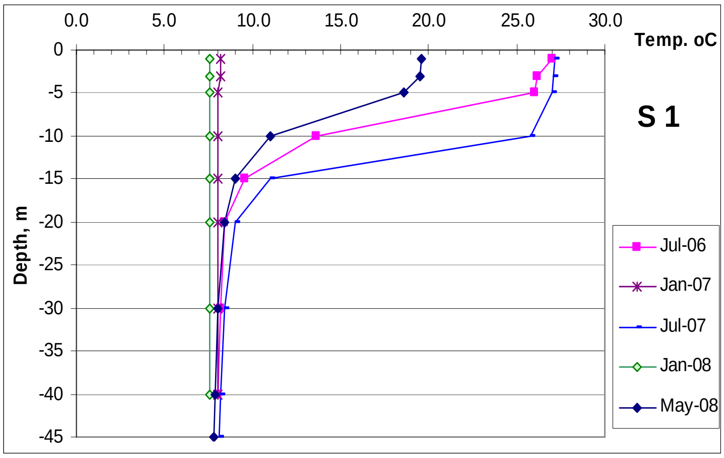

Figure 2. Five specific thermal situations in Bovilla reservoir: three fully developed stratifications and two overturns

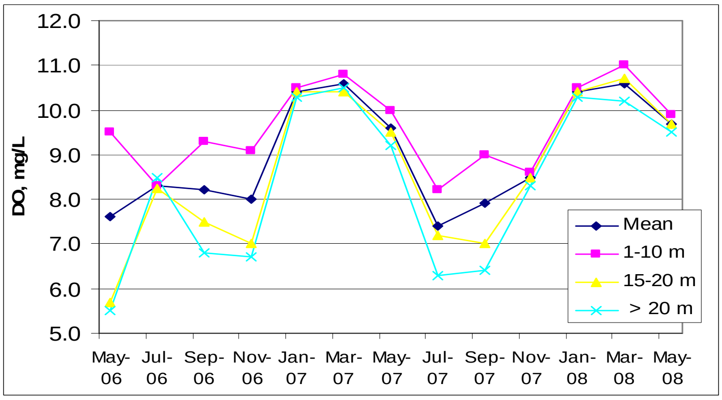

Figure 3. Mean DO concentration for entire water column and mean DO concentrations in three layers during two years monitoring

Surface DO levels were highest during period from January to March, declined through May, arrive the lowest levels on July and fluctuated during the fall. From the comparison of measured level of DO with level of oxygen saturation in water temperature results that the in bottom layers minimum level of saturation of water varies between 45-55% (two years mean resulted 73%), whereas maximum level in surface layers varies between 80-115% (two years mean resulted 98%). It can be concluded that water in Bovilla Lake is relatively well oxygenated during all the year, also in deep layers.

According EC Environmental Directive 440, guide level of DO for three quality classes are: for A1 > 70%; A2 > 50% and A3 > 30%. Nearly all lake water used for production of drinking water (usually taken from the depth 10-15 m) is of A1 quality. Only deep water during the stratification periods comply with A2 quality norms.

This Directive request also as guide level that BOD_5 (Biochemical Oxygen Demand) being ≤ 3.0 mg/L for A1, ≤ 5.0 for A2 and ≤ 7.0 mg/L O_2 for A3 quality level. From the data obtained from May 2007 to May 2008 result that all our samples analyzed complies with the norm of A1 quality: BOD_5 levels vary from 0.72 mg/L to 2.58 mg/L.

pH and Alkalinity: Although small changes in pH are not likely to have a direct impact on aquatic life, they greatly influence the availability and solubility of many chemical forms in the lake and may aggravate nutrient problems. Near neutral pH readings were recorded throughout the monitoring. Little horizontal variation in pH was observed: mean values varied between 7.64 and 8.33; minimum values between 7.39 and 8.15 and maximum values between 7.82 and 8.47. According EC Environmental Directive 440 guide level of pH for three quality classes are: for A1 6.5-8.5; A2 and A3 5.5-9.0. All our samples comply with A1 quality norm.

Alkalinity is a measure of naturally available bicarbonate, carbonate and hydroxide ions in water. In the range of pH situated in Bovilla water nearly all alkalinity is due the bicarbonate present. The mean values of alkalinity during different months are presented in Figure 4. Overall mean alkalinity value for all our samples resulted 156.3 mg/L HCO_3^- (n=175), with minimum 97.6 mg/L HCO_3^- and maximum 260.1 mg/L HCO_3^-. The results of alkalinity show that it a large calcareous region within the catchment area and these data support the conclusion of biogenic loss of $CaCO_3$ from the conductivity data.

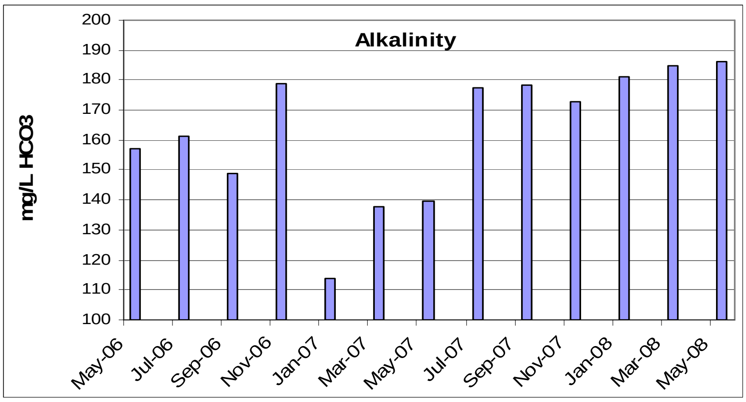

Figure 4. Overall mean values of alkalinity in water of station S1

Conductivity measurements: Conductivity is directly related to the content of dissolved ions in water. Levels of overall mean values during all monitoring study are presented in Figure 2. Only small variation can be observed during various months: the highest levels are measured during the dry season and the lowest – during the wet season. Overall mean conductivity value for all our samples resulted 307.4 µS/cm, with minimum 288.4 µS/cm and maximum 330.4 µS/cm. These data indicate biogenic formation of $CaCO_3$, also as colloid particles. It can be seen from Figure 5 that no distinct differences are in conductivity levels for all three sampling sites.

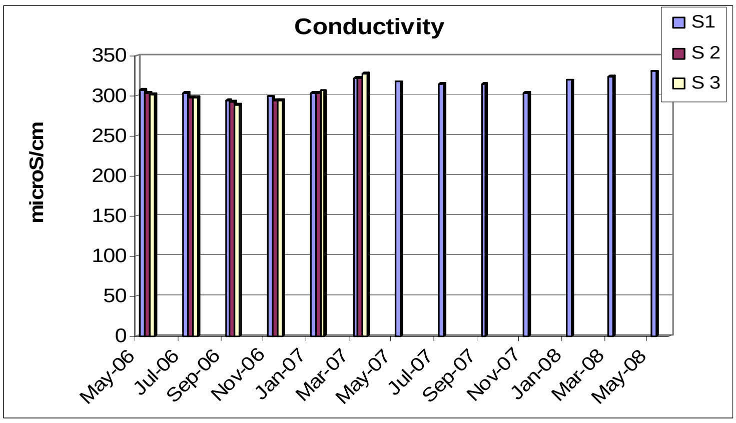

Figure 5. Mean conductivity levels (in µS/cm) during monitoring study

Conductivity values are much lower than guide norm of the CEC Environmental Directive 440 of 16/06/1975, "Quality of surface water intended for the abstraction of drinking water" (limit 1000 µS/cm for all quality classes). According EC Environmental Directive 440 guide level of TSS for quality class A1 is 25 mg/L. Not all our samples comply with this A1 quality norm. This Directive has not established a norm for turbidity. In some standards is requested a level not higher than 5 NTU. All our samples except those of November 2007 and January 2008 comply with this norm.

Turbidity and Total Suspended Solids Turbidity and TSS values vary for two main reasons – one physical, erosion from heavy rains and fast-moving water and the other biological, seasonal changes in algal growth. The nephelometric turbidity levels measured during the study period are shown in Figure 6.

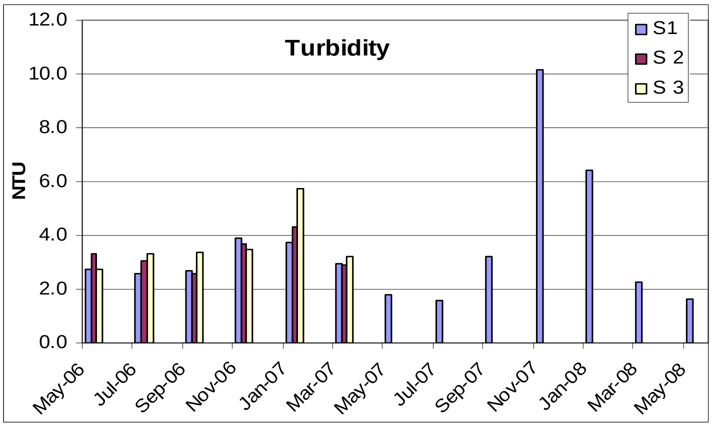

Figure 6. Mean turbidity levels in Bovilla reservoir during study period

Highest levels were found on November and January 2007 and November and January 2008, following heavy rains in the lake watershed. It can be seen that turbidity in site 1 is lower than values in sites 2 and 3, both being much closer to the income streams.

An important correlation with coefficient r^2 =0.711 (n=13) resulted between turbidity and quantity of rainfall for all our measurements. This obviously shows that erosion from heavy rains and fast moving streams are principal factor for high turbidity and TSS concentrations and not algal growth, cause chlorophyll *a* values in Bovilla reservoir are characteristic for oligotrophic level according OECD classification (OECD, 1982; Duka 2008).

Overall mean TSS value for all our samples resulted 39.87 mg/L (n=155). A strong natural correlation resulted between turbulence and TSS concentrations: r^2 = 0.88 (n=4) for the period July 2006 – March 2007 and r^2 = 0.995 (n=6) for the period July 2007 – May 2008.
According EC Environmental Directive 440 guide level of TSS for quality class A1 is 25 mg/L. Not all our samples comply with this A1 quality norm. This Directive has not established a norm for turbidity. In some standards is requested a level not higher than 5 NTU. All our samples except those of November 2007 and January 2008 comply with this norm.

Phosphorus Concentrations: Phosphorus concentration is of particular importance to this study because phosphorus commonly limits biological productivity of aquatic ecosystems. Total phosphorus (TP) measures all the organic, filterable and particulate forms of phosphorus. TP is generally measured when describing the phosphorus enrichment level of lakes and reservoirs because most of phosphorus in the system is in the particulate form and will assumedly be recycled within the water body in a form that is accessible to primary producers (Horne *et al.* 1994, Wetzel 2001).

Total phosphorus concentrations in Bovilla lake during two years monitoring period ranged from less than 2 μg/l (detection limit in our laboratory) to 14.7 μg/l; arithmetic mean concentration of 170 samples analyzed is 4.85 μg/l. EC Directive 75/440/EEC specifies two standards for soluble reactive phosphorus as guideline values: 400 μg/l for class A1 and 700 μg/l for class A2. All our samples comply the limit of the guide level A1.

Nitrogen Concentrations: Nitrogen (N) is another essential nutrient for living organisms. Nitrogen exists in fresh waters in a number of different forms. Most algae and other primary producers are able to utilize inorganic forms of nitrogen: nitrates (NO_3^-), nitrites (NO_2^-) and ammonium ions (NH_4^+) *(Smith 1996).* Nitrogen is primarily lost from lakes and reservoirs through the outflow, in an exchange

with groundwater, in the sediments, and by bacterial denitrification (e.g., converting NO_3^- to N_2), with subsequent loss of nitrogen gas (N_2) to the atmosphere *(Wetzel 2001).*
Nitrogen in water samples can be measured in several different forms:

- *nitrate-N= (*NO -N): Nitrate concentrations in Bovilla lake ranged from 0.02 mg/l up to 0.39 mg/l with an overall mean 0.172 mg/l (n= 176). Most of results comply A1 and A2 limits of guide levels.
- *nitrite-N= (*NO_2^--N): Nitrite concentrations in Bovilla lake ranged from 0.26 μg/l up to 27.5 μg/l with an overall mean 5.8 μg/l (n=176). All results comply with limits for Drinking Water Regulations of EC (0.1 mg/L) and for fish water (0.03 mg/L).
- *ammonium-N*= (NH_4^+-N): Ammonium concentration is important because ammonium appeared to be a marginally more effective source of nitrogen than nitrate. Nitrogen ammonium concentrations in Bovilla lake ranged from 0.01 mg/L up to 0.198 mg/L with an overall mean 0.0356 mg/L (n=173). All results comply with limits for A2 Guide and mandatory levels.

Conclusion

- From the physico-chemical parameters**,** the water quality of Bovilla lake comply well the norms of class A1 for raw drinking water quality standards of EC Directives “Quality of Surface Water Intended for the Abstraction of Drinking Water”, except few samples for total dissolved solids (TSS), ammonia and nitrates which comply the norms of class A2.
- DO levels are high during all year: epilimnion waters are always saturated and hypolimnion layer contains relatively high oxygen (min. 45-55%) and thus not presents anoxic situation.
- Reduction of erosion in watershed is perhaps the main factor to improve water quality and to increase the lifetime of the lake.

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