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DATA ON PHYTOPLANKTON OF BOVILLA RESERVOIR (TIRANA) FOCUSED ON DRINKING WATER USE

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Bovilla Reservoir, Tirana drinking water, phytoplankton, taste-and-odor in water.

SYNOPSIS

Since the year 1998, the Bovilla Reservoir is the main drinking water supplier for Tirana Capital and its suburbs (ca. 850’000 inhabitants). In an integrated study carried on during May 2006 – September 2008, low phytoplankton productivity was observed in; it was also supported also by other data, like photosynthetic pigments, zooplankton, etc. From biological, microbiological and other physical-chemical data the quality of waters corresponded mostly to oligotrophic state (I^{rst} water quality), category A1 of EC Directive 75/440. Relatively intense growth of phytoplankton was observed only in May 2007, corresponding to mesotrophic state (IInd quality). The most abundant species belonged to centric diatoms, represented mainly by *Cyclotella commensis*, not yet recognized to release substances that cause bed odor and taste in drinking water.

INTRODUCTION

An integrated study was carried out during October 2005 – September 2008 on the Bovilla Reservoir, the main source of drinking water (up to 1800 L/s) for Tirana capital and its suburbs (with more than 850000 inhabitants). The study aimed the knowledge of physical-chemistry and biology of the waters, and the human impact in its watershed; the purpose was to collect quality data that allow to determine its current limnology and to provide a first quantitative basis for the future water quality protection and monitoring. In September 2001, an unpleasant smell and taste, with an unknown origin started first to be manifested in drinking water. Since the year 2004, the Drinking Water Treatment Plant in Tirana added the treatment with powdered activated carbon (EC Directive 75/440) during the emergency period (October – April), increasing further the treatment costs of drinking water.

The Bovilla Reservoir was build up over Terkuza River in the year 1998. It has a surface of 4575 km^2, maximum volume of 80 x 10^6 m^3, and average depth of 18 m (max. 60 m, near the dam) (Fig. 1). The watershed of 98 km^2 extends about 15 km North-East of Tirana, in two municipalities, Zall Bastari (Tirana district) and Culli (Kruja district). More then 5600 inhabitants live in the watershed, shared in 9 villages, with the main activity livestock, woodcutting and some traditional agriculture. The human impact in the whole watershed is evident, mainly in northern and eastern slopes.

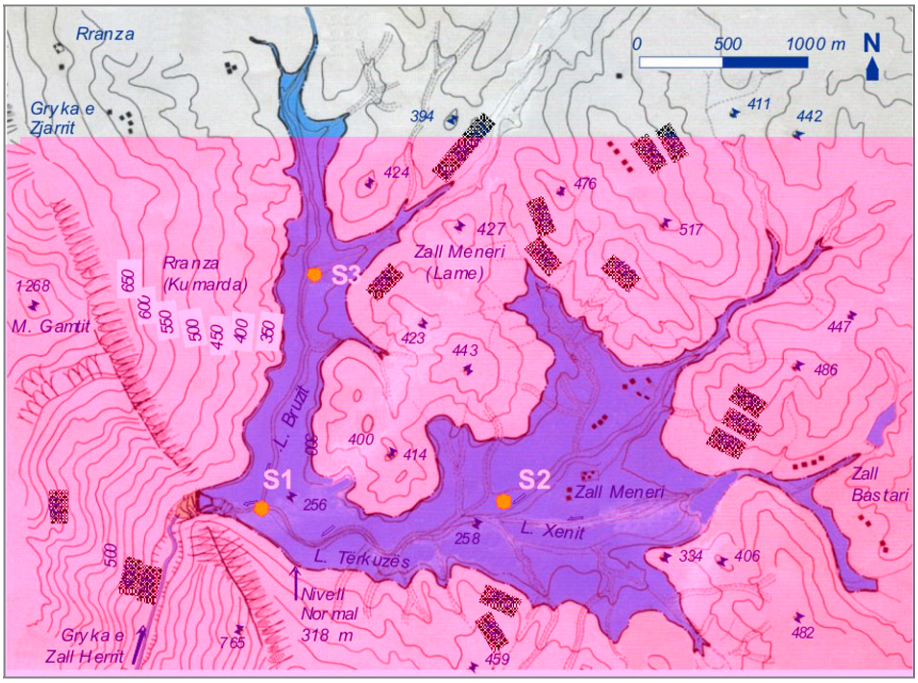


Figure 1: Topographic map of Bovilla Reservoir (1:25'000) with 3 sampling stations (S1, S2 S3) (*after Anonimous*, 1996).

The study was carried on in a joint project within the framework of SCOPES 2005-2008 program (Scientific Cooperation between Eastern Europe and Switzerland), financially supported by the Swiss National Scientific Foundation (SNSF). The data from the every working group were discussed and edited in a publication by MIHO et al. (2009a); it is also available on the website of Tirana University (http://www.unitir.edu.al/doc/fshn/BOVILLA(Albania)-WEB-PDF/000-0BOVILLA(Albania)-Pasqyra-Content.htm). Most of the physical-chemical aspects, nutrients and pigments were discussed by DUKA (2008) in her doctorate theses.

Limnological properties of Bovilla were summarized and discussed by ÇULLAJ et al. (*in press*). KUPE et al. (2008) reported preliminary data about phytoplankton in the Third ISEM and published in the Jurnal "Natura Montenegrina" (2008). Here we will discuss further the phytoplankton data, in an integrated way with other physical-chemical and biological parameters, focused more in the drinking water use, in odour and taste problems in the water.

MATERIALS AND METHODS

Water quality data have been collected bimonthly from May 2006 to September 2008. Depth profiles (1m, 3m, 5m, 10m, 15m, 20m, 30m, 40m) were obtained using a Ruttner bottle (2 L); during the first period of study (May 2006 – March 2007), samples were taken at three sites (S1, S2, S3; Fig. 1) and later only at the main site, near the dam (S1), as the differences between the three stations were negligible.

ÇULLAJ et al. (2009) assessed the main physical-chemical parameters: water temperature, pH, conductivity, dissolved oxygen, alkalinity, total dissolved solids, turbidity, permanganate index, UV absorbance, transparency; nutrients (phosphorus, nitrate, nitrite, ammonium), and the photosynthetic pigments. Phytoplankton was evaluated by KONI et al. (2009), and the zooplankton by SHUMKA and NIKLEKA (2009). The microbiological data (total coli, fecal coli and fecal streptococci) were also assessed by HOXHA and EMIRI (2009). MERSINLLARI et al. (2009) discussed about higher flora and vegetation in the surrounding watershed, the human activities and the human impact on water quality. To get some information about the compounds causing the smell and taste problems, two composite water samples integrating 0 to 10 m depth were taken in January 2008, during isothermic conditions (holomixis) and analyzed in Zurich; it was discussed by BACHOFEN and ÇULLAJ (2009). Moreover, water samples were taken from 1, 10, and 40 m, in September 2008, and distribution of the suspended particles were analyzed with flow cytometry also in Zyrich and discussed by BACHOFEN (2009).

Utermöhl method (1958) and EU Guidance Standard (EN 15204:2006) was used for the estimation of the phytoplankton (cell/ml). Water samples were collected in glass bottles (250 ml) and conserved in Lugol's solution. Cleaning of diatom frustules and preparation of the permanent slides was done in some cases as described by KRAMMER and LANGE-BERTALOT (1986-2001). Species determination was made following the keys of "Süßwasserflora von Mitteleuropa" KRAMMER and LANGE-BERTALOT (1986-2001) mainly. Examinations and counting's were made using sedimentation chambers 25 ml, with an inverse microscope Zeiss Auxiovert 25, with objective 40x, and with Zeiss, Axiovert 40CFL, objective 50x, the last one equipped with a digital camera. To get a reliable data (confidence 95%; error +/-10%) more than 400 cells were counted. From the quantitative data the approximate biovolume/biomass (1 mm^3/L = 1 mg/L) of phytoplankton was calculated (EN 15204:2006), based on the average cell volume of *Cyclotella* species, since they were the most abundant of the phytoplankton community (up to 98% during the intense growth); the trophy state of the waters was considered, using the classes of WILLÉN (2000). Linear correlation between different physical-chemical parameters and phytoplankton (cells/ml) were considered (after http://www.gifted.uconn.edu/ siegle/research/Correlation/corrchrt.htm). More detailed information was given by KONI et al. (2009).

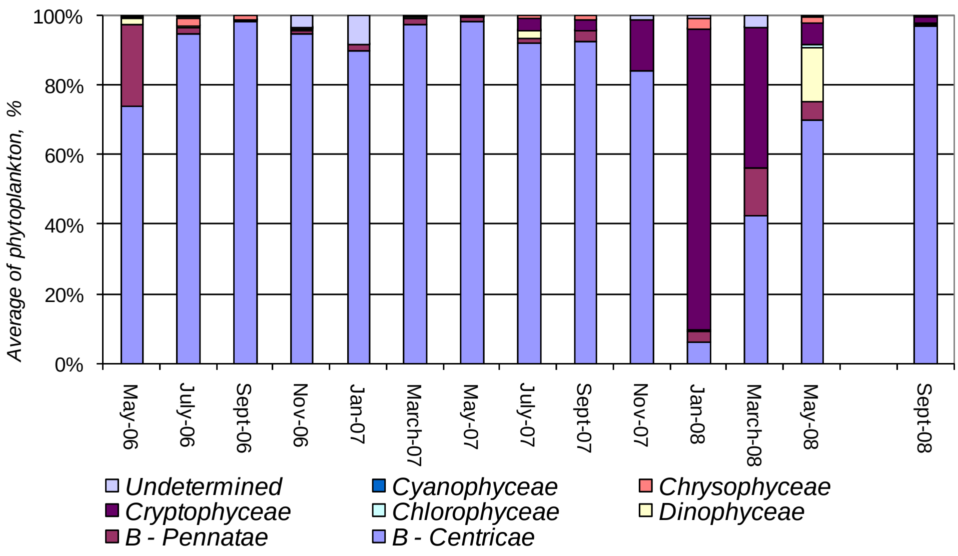
RESULTS AND DISCUSSION

More than 150 phytoplankton algal species were found in the Bovilla Reservoir. The centric diatoms, mainly *Cyclotella commensis* was the most common (Plate I: Figs. 1-2); other groups occurred scarcely or even only occasionally, such as *Dinophyceae, Chlorophyceae, Cryptophyceae, Chrysophyceae* and *Cyanophyceae*. *Cryptomonads* were the most abundant of them, especially during winter; they were represented mainly by species of *Cryptomonas* sp. *diverse* and *Rhodomonas minuta*. *Dinoflagellates* were present during the whole year, represented typically by *Ceratium hirundinella* (Plate I: Fig. 7), and various species of *Peridinium* (Plate I: Figs. 3-4 & 5-6), they were most abundant during the maximal growth of phytoplankton in summer. Common microscopic algae from the phytoplankton of the Reservoir were shown in Plate I. Total phytoplankton (cells/ml) at different depths is reported in table 1. KUPE et al. (2008) report also the depth profiles of phytoplankton (Fig. 3 in Kupe et al., 2008). The percentile of the principal phytoplankton groups that composed the phytoplankton for the sampling station S1 from May 06 to September 08 is given in figure 2.

In general, low photosynthetic productivity was observed related with the phytoplankton. Epilimnion and thermocline layers (1 to 15 m of depth) were the most productive, but only during thermal stratification, from May to September, with maximum growth in May (Fig. 3). In May 2007 an intense growth was observed, up to 9300 to 9600 cells/ml in the epilimnion (1 - 5 m of depth). For sure, the phytoplankton growth was conditioned by the meteorological and other climate features in the region. It was accompanied by moderate temperatures in epilimnion (ca. 20ºC). Relatively high productivity observed during the year 2007, probably was related with the relatively heavy rainfall, distributed mostly along the year, and with relatively moderate and high temperatures. During the maximum growth observed in May 2007, the rainfall was very excessive, more than 330 mm; in comparison, the rainfall values were respectively 55.7 mm in May 2006, and 28.4 mm in May 2008;

heavy rainfall furnish the Reservoir with more nutrients (mainly nitrogen and phosphorous), washed out from the surrounding watershed; combined with moderate temperatures in the region and in waters during spring period, it enhance the phytoplankton growth.

Figure 2. Dynamics of the principal phytoplankton groups (%), calculated after the average values (cells/ml) obtained for the whole water column, for the station S1 from May 06 to September 08.



The relative high dominance of only one species, C. *comensis*, especially during the summer period evidences the stressing conditions of the ecosystem. It is accompanied with high temperatures in epiliminion (up to 27ºC in July 2007), but also with scarce rainfall (0 mm in July and August 2007). The intense phytoplankton growth represented by only one dominant species, confirm that the Reservoir is still unstable, not in its normal natural state. It was also confirmed by a limited number and unstable composition of zooplankton species, compared to other lakes in the region (Shumka & Nikleka, 2009). Water level in the Reservoir and water uptake from the Treatment Plant in Tirana would be another important aspect that can influence in stressing conditions during summer. The water level in Bovilla oscillates drastically over the seasons, between the quotes 311 m to 318 m a.s.l. (= normal maximal level); the maximum level was observed during the wet period (February-April), due to the abundant inflow from the catchment; the minimum was observed in late summer-autumn (October to November) as a result of the scarce rainfall and a rather excessive use of water for drinking purpose.

Table 1. Total phytoplankton (cells/ml) in the Bovilla Lake at different depths, from May 2006 to September 2008.

Station & Date / Depth, m	-1	-3	-5	-10	-15	-20	-30	-40
S1-20/05/06	564	786	614	165	49	64	21	27
S2-20/05/06	821	525	798	279		25	16	
S3-20/05/06	745	827	214	356		28		
S1-15/07/06	1500	1104	1113	5618	1481	931	295	157
S2-15/07/06	1119	716	1818	2185		374	271	
S3-15/07/06	1521	1186	3513	3302		522		
S1-16/09/06	1008	646	613	6302	1346	506	89	54
S2-16/09/06	543	401	421	232		750	117	
S3-16/09/06	642	684	484	7355		185		
S1-18/11/06	1610	1799	1563	1709	785	1115	806	465
S2-18/11/06	1468	1459	2330	1623		685	573	
S3-18/11/06	1529	1659	1541	1488		473		
S1-13/01/07	154	147	85	188	154	91	88	89
S2-13/01/07	125	128	119	100		136	95	
S3-13/01/07	98	98	92	67		58		
S1-17/03/07	2021	2060	2006	1857	447	150	112	72
S2-17/03/07	2080	2371	1885	841		138	87	
S3-17/03/07	2672	1966	2325	2421		121		
S1-12/05/07	9689	9300	9341	5004	4521	3328	239	170
S1-23/07/07	1605	1526	908	3370	993	474	198	141
S1-16/09/07	848	875	1462	453	1564	418	212	108
S1-17/11/07	108	130	116	106	111	83	45	30
S1-19/01/08	330	306	345	338	333	157	23	2
S1-15/03/08	80	97	81	128	175	99	72	23
S1-17/05/08	555	412	483	243	193	86	101	22
S1-28/09/08	3034	3037	1688	1728	713	405	340	246

Approximate dynamics of biovolume (mm^3/L) of phytoplankton is shown in figure 4, calculated for the sampling station S1 from May 06 to September 08. The trophy state corresponded mainly to the oligotrophic waters, or first class of water quality after the trophy classes of WILLÉN (2000). Higher trophy state was found only in May 2007, corresponded to mesotrophic conditions, or second class of water quality. The same was confirmed also by ÇULLAJ and MIHO (2009), considering the content of phosphorous, photosynthetic pigments and other parameters. Considering the microbiological data, HOXHA and EMIRI (2009) confirmed that Bovilla waters belong mostly within the category A1, based in the EC Standard 75/440 concerning the quality required of surface water intended for the abstraction of drinking water; however, the human and animal impact cannot be considered negligible, with the numbers of fecal *Coli* and fecal *Streptococcus* detected, especially during the wet season (November-January) (category A2).

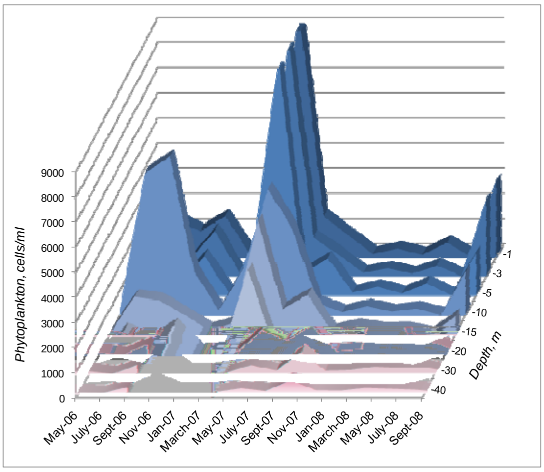


Figure 3. Dynamics of the phytoplankton growth (cells/ml) in different depths in the sampling station S1 from May 06 to September 08.

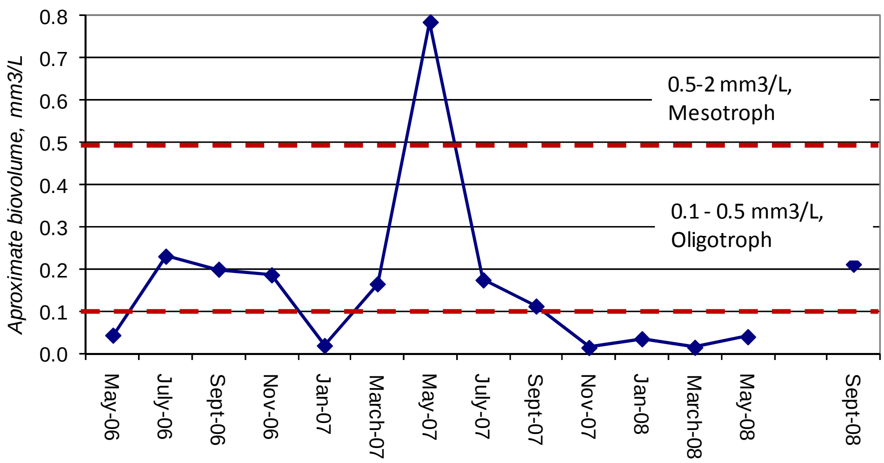
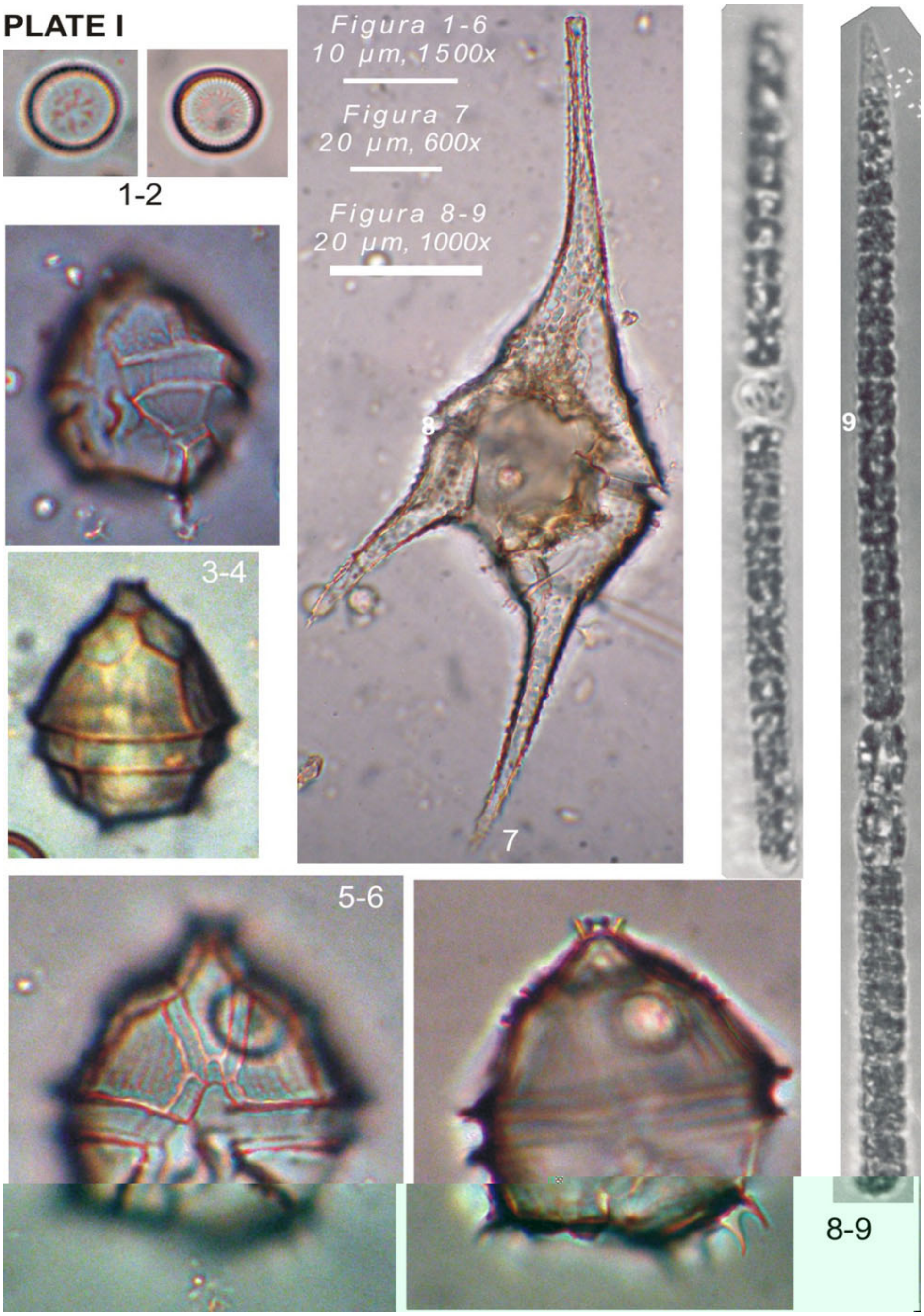


Figure 4. Dynamics of the approximate biovolume and/or biomass (mm^3/l = mg/l) of the phytoplankton for the sampling station S1 from May 06 to September 08, calculated from the average value in the whole water column.

PLATE I: Common microscopic algae from the Bovilla reservoir: Figure 1-2: *Cyclotella comensis*; Figure 3-4: *Peridinum* sp.; Figure 5-6: *Peridinium* cf. *umbonatum*; Figure 7: *Ceratium hirundinella*; Figure 8-9: *Anabaena* cf. affinis (Figures 1-6, 1500x; Figure 7, 600x; Figure 8-9, 1000x).



BACHOFEN (2009) compared the number of autofluorescent cells (particles) measured with Flow Cytometry in September 2008 with the related data of phytoplankton; it was observed that the number autofluorescent cells was 4 to 10 fold higher than what was counted with the inverse microscope. It means that we can aspect a higher primary production in waters, more than what we have estimated; it probably would be originated from small phototrophic bacteria or other picoplanktonic eukaryotic algae present in the water, which would have been overlooked and not counted by us. In the 40m sample (bottom) the proportion of SYTO-62 stained particles of the total, indicative for live cells, was clearly higher than in the two epilimnion samples, indicating again the dominance of heterotrophic bacterial processes in the bottom of the Reservoir.

Based on the water profiles of physical-chemical data, mostly the temperatures, the Bovilla Reservoir is a warm monomictic water body (Wetzel, 2001) that never freezes; it stratifies with high stability during the summer season. The epilimnion extends from 0 to 5 m of depth; the thermocline is located between 5 to 15 m; the water in the hypolimnion, below 15 m, is nearly isothermic with rather fresh temperatures, between 7.6ºC to 11.2ºC. During winter the whole water column is totally mixed, with respective temperatures of 8ºC (13/1/2007), 11ºC (25/11/2007) and 7.6ºC (18/1/2008); it is in relation this with the air temperature and winter climate in general. Dissolved oxygen was generally higher in epilimnion (80-115%; average value 98%) and lower in hypolimnion (45-55%; average value 73%); oxygen in hyplimnion was lower during the period of stratification (May to September). Nitrogen and phosphorus were generally low in the whole water column; total phosphorus was below 10 µg/L P-PO_4, with few exceptions where relatively high values were observed especially in the thermocline, i.e. 38.2 µg/L at 5 m depth in May 2006, and 57.8 µg/L at 10 m in September 2008; while ammonium increased during that period of stratification (Çullaj & Miho, 2009).

Significant positive correlation was found between phytoplankton (cells/ml) and related water temperature (Fig. 5). Dynamics of zooplankton growth showed some inertia in time (Fig. 6); the maximum growth of zooplankton was in September, not in May 2007 as it was observed for the phytoplankton (Shumka & Nikleka, 2009).

The species of the genus *Cyclotella* were the most abundant, i.e. up to 98% of the total phytoplankton during intense growfth of phytoplankton; *Cyclotella comensis* and other related species present, like *C. ocellata,* etc., were known to grow up in oligotrophic waters (Håkansson, 1989), with low nutrient content. Cyanobacteria, known to produce these volatile compounds, were only rarely present in phytoplankton. By GC-MS analysis of an integrated water sample (1-10 m of depth) taken in January 2008, a complex mixture of odor VOC were found, mainly monoterpenes, but neither Geosmin nor 2-MIB were detected (Çullaj & Bachofen, 2009). Furthermore, odor periods occur in the fall and winter period (Fig. 6), during isothermic state, when the temperature of the water was much lower than during the rest of the year. Smell and taste periods were closely related with some physical-chemical water parameters, such as the drop of temperature (ranging on an average from 22.4°C to 10.3°C), increase in turbidity, abundant rainfall, gradual increase of pH, maximum values of phosphorus and iron contents, but also with low phytoplankton and zooplankton biomass (Fig. 6). As mentioned in the literature (i.e. Lanciotti et al., 2003), the presence of odor during the winter, contradicts the cyanobacteria as the source of odors in freshwaters; it indicates that actinomycetes might be the major odor producers (Çullaj & Bachofen, 2009).

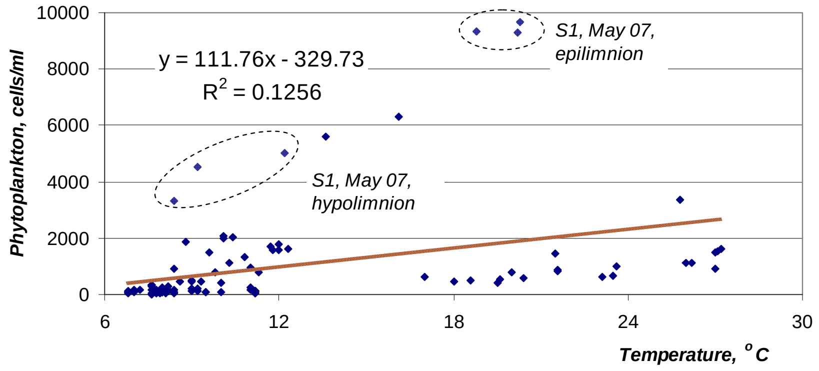


Figure 5. Linear correlation (r=0.354; df=102; p=0.01) between temperature (°C) and phytoplankton (cells/ml) in Bovilla (at sampling station S1), from May 06 to May 08. The related positions of the maximum phytoplankton growth in epilimnion and hypolimnion are enclosed in circles; r, correlation coefficient; df, degree of freedom; p, confidence level.

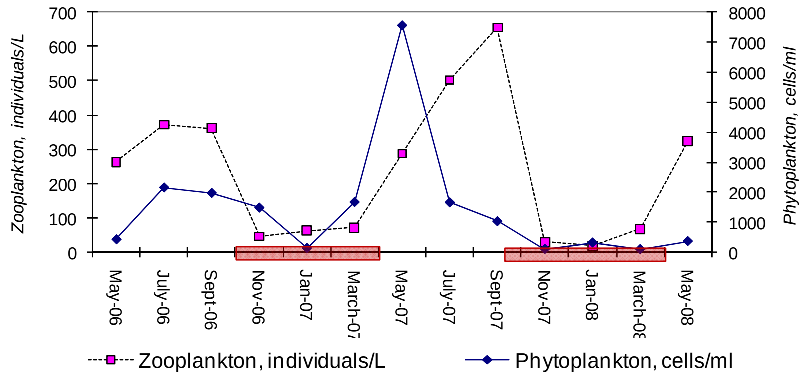


Figure 6. The time course of average of phytoplankton (cells/ml) and of zooplankton (individuals/L) in the water column 1-15 m in stacion S1 (Shumka & Nikleka, 2009) from may 2006 to September 2008; two bars show the periods of the treatment of drinking water with active carbon (respectively 6/10/2006 to 24/04/2007 and 17/09/2007 to 30/04/2008), combined with the periods of smell and taste evidence in raw water from Bovilla.

Aerobic filamentous actinobacteria with the actinomycetes (*Streptomyces*) are well known to cause taste-and-odor outbreaks in drinking water. They are mainly soil microbes that may enter the water through the wash-in of spores and during the vegetative phase; they can also be hosted inside of other microorganisms which may induce the excretion of volatile odor-causing metabolites, other than geosmin and MIB (Cross, 1981). We have not studied them yet, and our experience in Albania continues to be scarce related with the phenomena. But we strongly recommend that better knowledge of aerobic actionbacteria and their volatile compounds would help to know the cause of taste-and-smell problems in the raw water from Bovilla.

There is another important aspect evidenced during the study of Bovilla watershed. Beside the low productivity in phytoplankton and zooplankton, the waters showed always relatively low transparency (Secchi disk), that oscillated between 2.5 - 3 m of depth (see also Table 2 in Kupe et al., 2008). Suspended solids were relatively high, that several times exceeded 25 mg/L; also the turbidity was relatively high, classifying the water in the category A2, after the EC Standard 75/440. It was especially during the rainfall seasons, with relatively high concentrations of iron and nitrates, and bacterial pollution (fecal coliforms and streptococci). It evidenced the negative human impact in the watershed, enhanced also from the climate, the torrential character of rainfall and the schist-clay nature of the surrounding hills. Poor land use, scarce vegetation cover and strong erosion were evident in the zone, almost in the whole watershed area, as stressed also by MERSINLLARI et al. (2009). Therefore, the Reservoir was under the strong sedimentation process from the rivers, enhanced from the woodcutting, mainly for firewood, from overgrazing (especially from goats) and fires. Wastewater management from the local people and their livestock was also scarce. Poverty in the zone is quite evident, despite it is only few kilometers far from the Tirana capital. It was seen a low awareness related with water quality, not only in the zone, but also among the authorities in Tirana, interested directly to drinking water quality.

CONCLUSIONS

It is strongly recommended a sustainable management of the watershed focused on protection of water quality, preventing the erosion and the eutrophication phenomena; the most urgent measure would be the restoration of the vegetation cover, especially in the Protection Belt around the lakeshores (320-400 m a.s.l.); moreover, sustainable decentralized wastewater and sewage management should be applied in the zone, among groups or separated domestic households and farms.

Since the year 2006, Bovilla watershed is strictly protected, comprised within Dajti National Park (*extended*) (VKM, 402:2006). We stress that it is not sufficient if not accompanied by practical measures of protection and management, by an engagement to fight the poverty and protect the water quality, simultaneously.

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