ECOLOGIA BALKANICA

2010, Vol. 2 December 2010 pp. 1-6

Ecology of the Diatomic Flora in Thermo-Mineral Springs of Katlanovska Banja in the Republic Of Macedonia

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Abstract. Thermo-mineral waters have been attracting great attention in the world and in Republic of Macedonia lately, not only as a curative factor but also as an energy source. Thermo-mineral waters on the territory of the Republic of Macedonia are used for health-balneological purposes, and part of these since recently has been used in greenhouse economy.

Diatomic flora of the thermo-mineral waters in Macedonia is relatively poorly studied. Having in mind that the structure of diatomic flora of Katlanovska Banja has not been studied enough, and especially knowing that during the last two decades the taxonomy of diatoms has considerably changed, research of the diatomic flora of Katlanovska Banja has been started. Furthermore, these habitats are characterized by specific ecological conditions, which enable the development of characteristic diatomic micro-flora that is specialized for high temperatures (thermophilic species) and high content of salt (halophilic species).

The results of this research for the first time mention the presence of the genus *Nitzchia* in the thermal waters of Katlanovska Banja, not only as present, but also as dominant taxa. The discovery of the genus *Navicymbula* with the species *N. pusilla* is also very significant, because it was not known for the flora of the Republic of Macedonia.

Key words: diatomic flora, thermal springs, Katlanovska Banja, Macedonia.

Introduction

Diatoms are sensitive to many environmental variables, including light, moisture conditions, temperature, current velocity, salinity, pH, oxygen, inorganic nutrients (carbon, phosphorus, nitrogen, silica), organic carbon and organic nitrogen (e.g. KOLBE, 1932; VAN DER WERFF & HULS, 1957-1974; CHOLNOKY, 1968; WERNER, 1977). Therefore, they are considered to be powerful indicators for environmental changes, including acidification, eutrophication and climate changes, both in neo – and paleolimnological studies (e.g. DIXIT *et al.*, 1992; VAN DAM, 1993). Such studies often use autecological data, which are taken from the available literature. LOWE (1974) and BEAVER (1981) have compiled many data from the literature, but many important Western – European freshwater taxa are missing in these reports. The lists by DE WOLF (1982) and DENYS (1991) are containing a lot of useful literature data on the ecology of diatom taxa, but, as stated before, they do not cover all the diatom taxa in the Netherlands. The indices for the species recorded follow the list of the Netherlands freshwater diatoms, with ecological indicator values for those environmental variables which are

considered to be the most important ones in aquatic and wetland ecosystems in The Netherlands: moisture conditions, pH, trophic state and salinity (HIGLER, 1991; VERDONSCHOT *et al*., 1992; VAN BEUSEKOM, 1993). Measures against pollution by organic biodegradable material are a major issue in water quality management for many years (SMIT-KROES, 1989). Because diatoms are very susceptible indicators for such pollution and the associated changes in the oxygen balance (HUSTEDT, 1957; CHOLNOKY, 1968; SLADEČEK, 1986), we include indicator values for saprobity, organic nitrogen and oxygen as well. A unique eight – letter code (acronym) is assigned to each taxon to facilitate electronic date processing.

A thermal group of waters consists of mineral waters that that are distinguished from regular cold waters in their temperature and as such they have a number of applications in balneology, for heating settlements, greenhouses, and for getting electrical energy. This group of mineral waters is called thermo-mineral waters in literature. They are underground waters with temperature higher than the mean annual temperature of a particular location as high as 100°C.

The thermo-mineral waters in the Republic of Macedonia are used for health-balneological purposes: Bansko - Strumica, Banja - Kocansko, Negorska Banja-Gevgelija, Katlanovska Banja – Skopje, Kezovica – Stip, Proevska Banja – Kumanovo, Baniste and Kosovrasti – Debar (KOTEVSKI, 1987). For Katlanovska Banja the same author reported totally 23 taxa of 16 genera, while for Bansko - 29 species of 15 genera with greater representation of the taxa belonging to the genus *Navicula*. A slightly richer diatomic flora was reported in Debarska Banja where totally 34 diatomic taxa were determined. These thermo-mineral waters are dominated by the genus *Denticula* (STOJANOV, 1983). Likewise, the author listed several new taxa in the flora of Macedonia that are considered to be rare, i.e. their distribution in Macedonia is limited.

The aims of the current paper is to establish the structure of the diatomic flora of Katlanovska Banja; to establish rare or potentially new species in the flora of the Republic of Macedonia; to make valorization of habitats based upon the structure of diatomic taxa.

Material and methods

Study area. The tectonic structure of the terrain is of special significance for the formation of thermal, thermo-mineral, and mineral deposits of spring waters. In this sense the terrain neo-tectonics is particularly important. Most of thermal and thermo-mineral waters are found in the area of the tectonically unstable Vardar zone, and in the area of western Macedonia and regions directly connected with them. These tectonic faults are seismically active even today and, as such, they belong to areas with high level of seismic activity. Katlanovska Banja – Katlanovo belongs to Vardar zone.

Sampling methods. The algological material was collected from the stones, edges and bottom of springs and their flowing-out waters, from the rocks and scale across which thermo-mineral water flows out, from materials of concrete and wooden troughs of thermo-mineral taps, and from various objects immersed in water. At the same time, while collecting material, the environment reaction was measured - (pH-6,5-7).

Microscopic analyses were made by means of Microscope Nikon Eclipse E-800, and the micro-photographs were made with Nikon Coolpix camera. The valve of respective species is represented 1500 times enhanced.

Results

Taxonomic analyses

The analyses of the collected material showed the presence of the following species:

Genus *Navicymbula*

N. eriguga, N. cinata, N. Pusilla (Fig. 1-3)

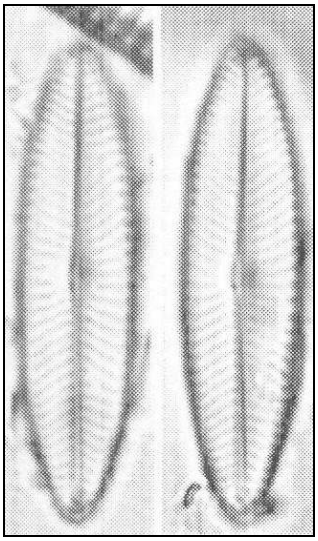

Fig. 1. *Navicula erifuga*

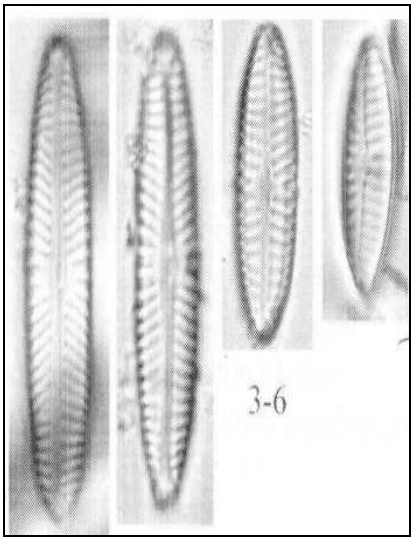

Fig. 2. *Navicula cinata*

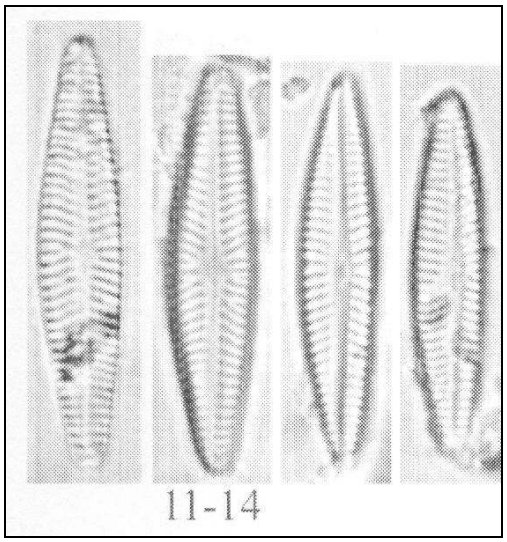

Fig. 3. *Navicymbula pusilla*

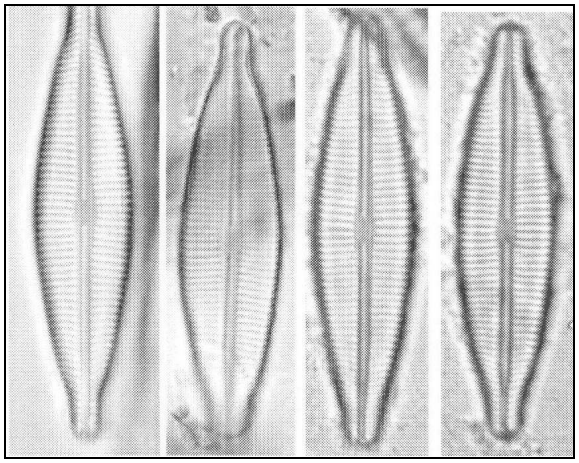

Fig. 4. *Craticula buderi*

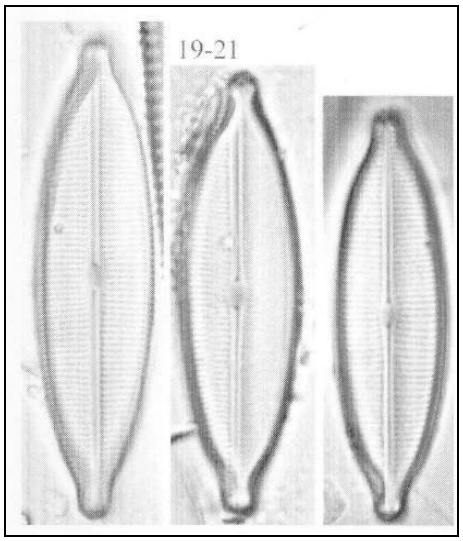

Fig. 5. *Craticula hlophilla*

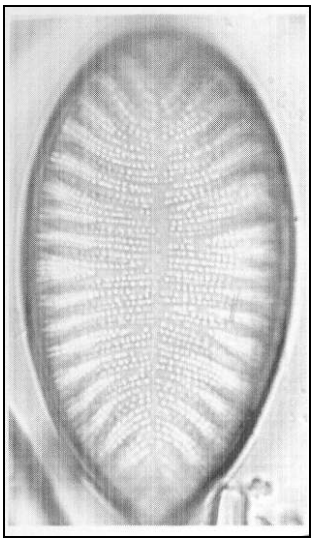

Fig. 6. *Surirella katlanovicensis*

Valves moderately dorsiventral, semi-lanceolate with moderately arched dorsal and convex or approximately straight ventral margin. Ends rounded, not protracted. Length 14-42 μm, breadth 3,9-7,2 μm, maximum length/breadth ratio 6. Axial area narrow, straight, linear or broadening gradually towards valve centre to form a narrow, lanceolate space.

Central area absent or not well expressed. Raphe filiform, proximal ends slightly expanded and barely ventrally displaced the ends dorsally deflected teminal fissures dorsally deflected following subterminal ventral deflection. Striae radiate, becoming parallel to slightly convergent towards the ends. Around the central nodule one to several striae distinctly shortened. Striae in the Lm very delicate, in the middle portion (dorsal) 15-18/10 μm, up to 20/10 μm towards the ends, lineolae (not recognized in the LM) 40-50/10 μm.

Genus *Craticula* (Fig. 4-5)
C. buderi, C. hlophilla

Distribution: Cosmopolitan, fairly common in the area covered by the flora. Its tolerance to trophy and saprobity is very broad, ranging from weakly meso- to hypereutrophic, and oligo- to α-mesosaprobic. It is also found in periodically wet habitats, e.g. moist meadows, and industrial effluent.

Genus *Surirella*
Surirella katlanovicensis (Fig. 6)

The surface of the valve is almost planar. Between the well developed traxapical undulations there are bi- or triseriate striae with one-sided areoles. The canal raphe is almost in the same plane with the surface of the valve itself. On the inside the canal is supported only by fibulas of Type 2 that bridge the distance between the face and the side of the valve. Between each two fibulas there is a big opening, portulaca, through which they communicate with the canal raphe. The apix (the wider end) of the valve has a continued raphe on the inner side, i.e. the proximal ends of the raphe are absent. Having in mind that raphe is quite slightly raised; there is no ridge, alar canals and punctae.

Discussion

According to the algological research in Katlanovo, STOJANOV (1982) found 23 taxa that belong to 16 genera. Eighteen of these are determined as species, and 5 are determined to be at the level of varieties. It was found that the genus *Navicula* represented with 5 taxa is most present in the thermo-mineral waters in Katlanovo, and 10 genera are represented with only one taxon, while the thermophilic species *Achnanthes gibberula* Grunow gives an essential characteristic to the Katlanovo thermae where it is the most dominant taxon. Frequent forms that were not previously reported in the algae flora in former Yugoslavia are: *Achnanthes gibberula, Navicula thienemanii*, *Caloneis hultenii*, *Rhopalodia giberula* var. *vanheurckii*, *Surirela margaritacea*. The diatoms in the thermo-mineral waters in Katlanovo are best developed in the sites with water temperature of 31°C where *Achnanthes coarctata* (Brébisson) Grunow and *Gomphonema parvulum* (Kutzing) Grunow are most frequent, and the poorest are the thermae with water temperature 54,5°C where only single samples were found of *Diatoma vulgare* Bory, *Gomphonema olivaceum* (Lyngb.) Kutzing and *Rhopalodia gibberula,* and slightly more often *Caloneis hultenii* Boye P., a typical inhabitant of warm springs up to the temperature of 45°C (STOJANOV, 1982).

The diatomic flora in the thermo-mineral waters of Bansko is richer than the one in Katlanovo thermae. In the much warmer thermae in Bansko 29 diatomic flora were reported (of 15 genera) of which 21 were determines as species, 8 as taxa at lower taxonomic level (6 varieties and 2 forms), and, unlike Katlanovo, all the reported diatomic forms belong to the class Pennatae (STOJANOV, 1982). The most represented genus in the thermo-mineral waters of Bansko is *Navicula,* represented with 6 taxa, then the genus *Pinnularia* with 4, and the genus *Achnanthes* represented with 3 taxa, and 10 genera represented with only one taxon each. The thermae in Bansko are particularly characterized by the genus *Denticula* with the species *Denticila elegans* Kützing, *D. thermalis*

Kützing, and *D. tenuis* Kützing as dominant in the researched area (STOJANOV, 1982). Some species were reported in the thermo-mineral waters of Bansko that were not previously reported in the algae flora in former Yugoslavia (*Pinnularia braunii* (Grun.) Cl. *Denticula thermalis*, *Nitzschia vitrea* Norman).

The research of the Katlanovo thermae area in February 2007 showed that thermal waters are characterized with constant reaction of pH 6,8-7,2 and temperature of 38˚C.

As a result of the algological research it was reported that the genus *Nitzschia* was found for the first time, which, according to Stojanov's research (STOJANOV, 1982; 1984), was never present in Katlanovo thermae, but was listed in the results of the algological research of the Debar thermae. Comparing the results from 2007 with the above mentioned Stojanov's results, the following was reported: Besides the genera listed by STOJANOV (1982) there are some new ones that have not been mentioned in the diatomic flora of Katlanovo thermae, such as: *Amphora, Cocconeis, Denticula, Navicymbula, Planothidium, Ulnaria* and species *Eolimna minima, Fallacia insociabilis, Tryblionella constric,* while in Stojanov's results (STOJANOV, 1982) there is *Pinnularia interrupta* f. *minor*, but was not reported the algological testing in 2007.

It is interesting that in 1982, Stojanov reported hat the genus *Nitzschia* was not present but in the algological results in 2007 it was reported to be the dominant species results (STOJANOV, 1982).

In comparison to the algological research of Debar thermae and Stojanov's statements in 1984 that *Nitzschia* was present in Debar and absent in Katlanovo thermae results (STOJANOV, 1984), according to the results of the research in 2007 it can be stated that *Nitzschia* is a common taxon of Katlanovo and Debar thermae. The reported species present in Katlanovo thermae but absent in Debar thermae are: *Mastoglioaeliptica sp., Navicymbulla pusilla, Planothidium lanceolatum, Rhopalodia* spec. *gibberula, Surirella ovalis, Tryblionella constricta.*

When compared to the algological results of Bansko thermae and Katlanovo thermae (by STOJANOV 1982, 1984) and to the results from February 2007, it was reported that instead of *Achnanthe* as dominant there was *Nitzschia* as dominant species, which, again by Stojanov, was not reported in Katlanovo thermae.

All upon mentioned diatom flora are results from several analyses made by STOJNOV (1982, 1984) *Surirella katlanovicensis,* is different from other *Surirella* sp.

Conclusions

According to the results concerning the area researched for the presence of diatomic flora in the thermo-mineral spring of Katlanovska Banja, the following conclusions can be made:

1. The final analyses of the results determined a total number of 40 diatomic flora. The determined representatives are mostly highly specialized for thermal and thermo-mineral waters, in other words, they mainly belong to the group of thermopile and hemophilic species. This research has determined a considerably large number of species in terms of the previous research; this is probably the case due to a large number of substrates and a more detailed microscopic analysis.

2. The presence of the genus *Nitzschia* was mentioned for the first time, not only as present, but as dominant species in the thermae of Katlanovska Banja. The following species are present in this genus: *Nitzschia communis, Nitzschia linearis, Nitzschia sigmoidea, Nitzschia amphibia-small, Nitzschia vitrea.*

3. Several taxa are determined that can not be identified on a genus level at the moment. These are considerably different in comparison to the already known species. It is supposed that these represent new species for the science. A typical example is *Surirella* sp. which belongs to the complex around *Surirella ovalis,* but it is considerably different in density and shape of the areoles.

4. The finding of the genus Navicymbula is also significant with the genus Navicymbula pusilla that has so far been unknown in the flora in the Republic of Macedonia. This result suggests that additional research of a large number of thermo-mineral waters in Macedonia is necessary in order to determine the total diversity of the diatoms, as well as

establishing highly-specialized species for life in these conditions. It is necessary to conduct detailed research in different weather seasons with more detailed electron-microscopic research.

5. Everything that is given in this part is a description on diatomic flora found at the place of research, there are several species like: *Nitzschia communis, Nitzschia linearis, Nitzschia sigmoidea, Nitzschia amphibia-small, Nitzschia vitrea,* and these taxa were not found another previous result from other researchers like dominant species.

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Received: 21.08.2009
Accepted: 14.05.2010

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