SANITARY PARAMETERS OF WATER FROM SECU AND VĂLIUG DAM RESERVOIRS, CARAŞ-SEVERIN COUNTY (ROMANIA)

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Abstract. The study consists in determining the sanitary groups of bacteria from the waters of the Secu and Văliug dam reservoirs. The two reservoirs serve several functions, mainly to guarantee drinking and industrial water for Reşiţa city, energetic, flood and wave mitigation, turistic recreation and fishing. Sanitary water quality has been assessed by quantifying the presence of pathogenic indicators and their seasonal and annual variation during two years, 2009 and 2010. The water samples were collected seasonally from different points- dam, middle, tail- and dephts. There have been studied three sanitary indicators: total coliforms, faecal coliforms and faecal enterococcus. Data analysis showed decreasing trends for total coliforms in both reservoirs and for faecal coliforms in Secu Lake, but an increasing tendency for faecal coliforms in Văliug Lake, which may occur due to massive human activities and faeces domestic pollution.

The conclusion based on the evaluation of the results is that the numerical density of sanitary bacteria was low in the majority of the collection points. The maximum values were recorded in the peripheral-anthropic areas and in the depths of both lakes.

Of all groups of evaluated bacteria, the coliform have shown the maximum values while the faecal enterococcus had the minimum values, even undetectable ones in some samples.

Keywords: sanitary indicators; faecal contamination; drinking water; Secu and Văliug dam reservoirs

INTRODUCTION

"Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all" [40]. The water crisis is a well known issue on a world wide scale (Fig. 1). The water of rivers and lakes represents only 0.00009% of the hydrosphere [33, 37].

Because of many intense pressures on water resources, the creation of legislative instruments that clearly address the appearing problems and contribute to the guarantee of water resources for the next generations became essential.

Thus the dam reservoirs with water used for drinking have to fulfill some quality conditions before entering in the tratament plant. Therefore, according to the Water Framework Directive the thoroughly study of these waters from biological and microbiological point of view is essential in order to find the impact ways and to apply the suitable control methods for rehabilitations and maintaining the water quality at a very good potential [10].

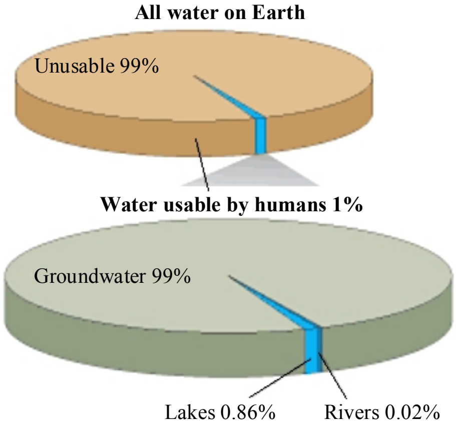

Figure 1. Water on Earth (http://ga.water.usgs.gov/edu)

The prevention of microbial and chemical contamination of source water is the first barrier against drinking-water contamination of public health concern. An improved source is one that, "by nature of its construction, adequately protects the source from outside contamination, particularly faecal matter" [39, 42]. Current practices involve multiple barriers to remove raw water pollution and to control bacterial regrowth in distribution systems [4]. Water resource management and potentially polluting human activity in the catchment will influence water quality downstream and in aquifers. This will impact on treatment steps required to ensure safe water, and preventive action may be preferable to upgrading treatment [41, 43]. If the water of Earth showing if all Earth (liquid, ice, freshwater, saline) was put into a sphere it would be about 860 miles (about 1.385 kilometers) in diameter [38].

Observations over the past few years, especially 2010 and 2011 show a dramatic water volume decrease for both lakes as a consequence of global warming as well as of an overconsumption of water, as this lakes serve as drinking water source for the town of Reşiţa. The centre point of the 4th Congress of European Microbiologists" organized by the Federation of European Microbiological Societies (FEMS) in Geneva in July, 2011 was the ecological approach of microbial processes, while the key words of the conference were "world of microbes" and "solutions to future challenges". It is time to breach the institutionalized dichotomy between environmental science and biomedical research and to study ourselves as an integral and dependent part of our microbe-dominated world [22].

They may play a beneficial role in drinking water treatment, as biological filters, but on the other side, detrimental effects of biofouling consist in microbially induced corrosion, disinfectants depletion, aesthetic problems i.e. colour, odour and taste degradation and microbiological deterioration of drinking water by hosting and releasing pathogenic or toxins producing bacteria, viruses, protozoa, fungi, algae and invertebrates. In a drinking water system, about 95% of the bacterial numbers were estimated to be located at the surfaces, while only 5% were found in the water phase and detected by sampling as commonly used for quality control [12, 14]. Drinking water-associated biofilm may harbour pathogenic species, thus representing a potential reservoir for water contamination [13, 29, 35].

Caraş-Severin is a county in the Banat region of Romania, situated in the southwest of the country. It is considered a mountain county, rich in rivers. The micro-zone Reşiţa is crossed by the River Bârzava, which springs from the west side of the Semenic Mountains from an altitude of 1241 m. The Bârzava springs are characterized by reduced flows with a large fluctuation during the year depending on the amount of precipitation [27].

Secu Lake: dam reservoir, Bârzava drainage basin, 350 m altitude, 105.67 ha surface, water volume of 15.132.000 m^3, Semenic Mountains. Built in 1963, it supplies water for Reşiţa town and also has a recreational role for Secu resort, although this implication is not legal. Secu accumulation is the most important source of raw water for the city of Reşiţa.

Văliug Lake: dam reservoir, Bârzava drainage basin, 500 m altitude, 66.2 ha surface, water volume of 11.732.000 m^3, 40 m deep, Semenic Mountains. Built in 1963, it serves as water supply for Secu lake, situated downstream, and implicitly for Reşiţa town. It also represents an attraction for Crivaia Resort. This lakes represent significant aquatic ecosystems and demand for an increased conscientiousness towards the observation of the microbial evolution of the sanitary quality and of the sediments [27].

MATERIALS AND METHODS

The bacteriological analysis from water were performed during April 2009 and November 2010. From the water of the Secu and Văliug dam reservoir were taken sesonally, from surface but also from different dephts in a vertical profile of the lake's water.

The analysis of water samples was performed in the labs of Aquacaraş and Microbiology Lab of Biology and Geology Faculty from Babeş-Bolyai University, Cluj-Napoca. The sampling procedure and sample transportation, preservation and preparation for analysis were performed according to specific standards. All microbiological determinations in present study are based on conventional methods, targeting viable and cultivable microorganisms growth on general or specific culture media [5, 11, 36].

Faecal indicators were isolated according to the standard methods used in drinking water quality assessment. Total coliforms and faecal coliforms were detected and quantified via most probable numbers (MPN) technique [5]: inoculation of 10, 1, 0.1 and 0.01 ml samples in Mac Conkey broth, incubated for 48 hours at 37˚C (presumptive test), followed by total coliforms confirmation on Levine EMB Agar (24h at 37˚C) and faecal coliforms confirmation on Brilla Broth, 24h at 44˚C [35, 37].

Sanitary water quality is assessed by the presence or absence of pathogenic microorganisms or their indicators. By bearing of a potential pathogen, the water could endanger health and even life. The key parameters of bacterial contamination of water and sediments are: total coliforms and faecal coliforms and faecal enterococci. According to the isolated or associated presence of such bacteria, as well as their quantitative seasonal and annual variation, an assessment of the state sanitary and hygiene water and sediment may be done [13, 41].

Statistical analysis were carried out using Microsoft Office Excel programm.

RESULTS

Bacterial pollution from human and animal sources is a significant problem associated with the degradation of water quality [17]. A series of anthropogenic activities have produced significant changes in composition and abundance of phytoplankton communities and in the water quality in the lake [31]. Accounting for faecal contamination of drinking water sources is an important step in improving monitoring of global access to safe drinking water. In the absence of faecal indicators in treated water, heterotrophic plate counts (HPCs) constitute a standard tool to assess general microbiological quality [15].

Physico-chemical parameters were within the normal range (Table 1). Temperature had a positive influence on the bacterial density. The organic mater represented by CCOMn influencing also pozitively the structure and activity of the microorganismus communites. The concentration of the dissolved oxigen has been higher in Văliug dam compared with Secu dam reservoir. No significant differences were found between water samples collected.

Using statistical analysis (Microsoft Office Excel program the existence of significant connection between sanitary indicators and temperature, dissolved oxygen and organic material, key factors in the development of microorganisms, has been demonstrated (Table 2).

For the Secu Lake the total coliform bacteria correlate positive with temperature and with the amount of organic matter (CCOMn), the pH value does not correlate or correlates negatively and in few of the analized sections.

The most powerful correlation of the total coliform bacterium with temperature was obtained in 2009 in the surface area of the water, northwards of the dam (r=0.999407) and in 2010 southwards and from tail (r = 0.995498).

Table 1. Details the physic and chemical characteristics of Secu and Văliug Lakes water column

Parameters	Units	Lake	Max	Min	Average
pH	pH units	S	6,95	6.7	6.87
		V	6.94	5.70	6.54
Temperature	°C	S	30.8	1	12.4
		V	22	0.6	9.24
Turbidity	NTU	S	41	2.31	5.14
		V	26.59	1.33	3.16
Color	mgPt/L	S	69	18	39
		V	46	17	24
Dissolved oxygen	mg/L	S	12.50	7	9.25
		V	14.80	8.2	10.197
BOD	mg/L	S	3.5	1.7	2.11
		V	2.6	1.4	1.92
COD	mg O_2 /L	S	5.90	1.30	2.32
		V	4.42	1.04	2.14
Ammonium	mg/L	S	0.155	0.017	0.086
		V	0.093	0.023	0.053
Nitrites	mg/L	S	0.127	0.002	0.077
		V	0.015	0.004	0.016
Nitrates	mg/L	S	1.88	0.8	0.88
		V	2.88	0.445	2.13
Total P	mg/L	S	0.066	0.025	0.0343
		V	0.046	0.0187	0.02
Total N	mg/L	S	1.27	0.425	0.53
		V	1.42	0.34	0.476
Chlorides	µg/L	S	2.97	0.64	1.93
		V	2.63	0.62	1.81
Sulphates	mg/L	S	10.33	4.22	6.22
		V	10.5	0.86	4.54
Conductivity	µS/cm	S	253	26.7	94.5
		V	198	26.3	50.8
Total iron	mg/L	S	2.781	0.03	0.281
		V	2.28	0.04	0.28
Hardness	d^0 G	S	3.40	0.86	1.88
		V	2.2	0.44	1.22

S = Secu Lake, V = Văliug Lake, BOD = biochemical oxygen demand, COD= chemical oxygen demands

Table 2. The correlation between total coliform bacterium and the physico-chemical indicators from the Secu dam reservoir in 2009 and 2010

Sampling sites (Col. T)	T(^{0}C)		**pH**		**OD**(mg/l)		**CCoMn**(mg/l)	
	2009	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
Dam N	0.999407	0.955635	-0.03474	0.001942	-0.9992	-0.99485	0.848134	0.774529
Dam center	0.995467	0.96394	-0.41537	-0.26337	-0.99678	-0.99776	0.873813	0.932234
Dam S	0.993587	0.986484	-0.15177	-0.14485	-0.91415	-0.99743	0.931879	0.850917
Middle N	0.777859	0.995853	-0.68755	-0.59711	-0.86054	-0.86673	0.853293	0.752602
Middle center	0.987882	0.990705	-0.3509	-0.31611	-0.99998	-0.98851	0.875961	0.712787
Middle S	0.951117	0.992365	-0.30246	-0.35874	-0.99902	-0.98113	0.983031	0.979134
Tail	0.976286	0.995498	-0.23633	-0.1773	-0.99364	-0.99999	0.997132	0.985404

Table 3. The correlation between total coliform bacterium and the physico-chemical indicators from the Văliug dam reservoir in 2009 and 2010

Sampling sites (Col. T)	**T(^{0}C)**		**pH**		**OD** (mg/l)		**CCoMn** (mg/l)	
	2009	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
Dam N	0.982827	0.977115	-0.5849	-0.35437	-0.99468	-0.94286	0.947063	0.853224
Dam center	-0.42661	0.975754	0.359729	-0.58521	-0.1332	-0.99961	0.938176	0.983654
Dam S	0.823529	0.951695	-0.18502	-0.23882	-0.96915	-0.97946	0.804135	0.942953
Middle N	0.627051	0.880275	0.163391	-0.29236	-0.76457	-0.58476	0.968158	0.999161
Middle center	0.546475	0.570251	0.298373	-0.28029	-0.55034	-0.61993	0.997129	0.771269
Middle S	0.986795	0.938354	-0.36142	-0.37059	-0.95508	-0.71462	0.89829	0.876108
Tail	0.991693	0.927303	0.134399	0.088228	-0.98943	-0.91304	0.999344	0.988813

Very strong but negative correlations were established between coliform bacteria and dissolved oxygene for all water sections analysed for the Secu Lake.

In 2009, the total coliforms and temperature correlation oscillates with the pH between significant, positive and very good correlation (r = 0.9867) and is very low and negative (r = -0.38605) in the centre of the dam as well as between low to very low, both positive and negative.

In 2010, the correlation with temperature is very good while the correlation with pH is negative.

Strong but negative correlations were established for almost all water sectors with dissolved oxygene (OD) and positive in case of the amount of organic matter (CCOMn) in 2009 and 2010.

The exception is the middle area of the lake where there is a significant but moderate correlation with dissolved oxygene.

Faecal contamination of drinking water is monitored using faecal indicator bacteria [19]. Concerning bacterial activity, the human microbiome is the enormous community of microorganisms occupying the habitats of the human body. Different microbial communities are found in each of the varied environments of human anatomy. The aggregate microbial gene tally surpasses that of the human genome by orders of magnitude. The relationship of the microbial content to health and disease is one of the primary goals of human microbiome studies [26].

The Figure 2 and Figure 3 shows the distribution of the annual average values for the density of sanitary bacteria in 2009 and 2010, in the analysed lakes.

Since the mesophilic bacteria are heterotrophic and their presence in water, as a natural environment, is normal we highlighted in the figure the significant bacterial indicators for the water sanitary status, that are: total coliforms, faecal and enterococci.

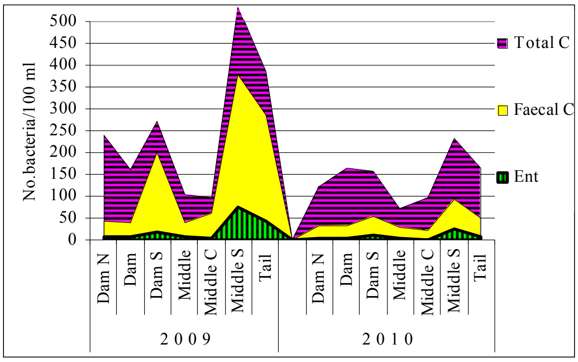

Figure 2. Distribution of the annual average of the sanitary bacteria in Secu Lake (Total C = total coliforms; Faecal C = faecal coliforms; Ent = Enterococcus)

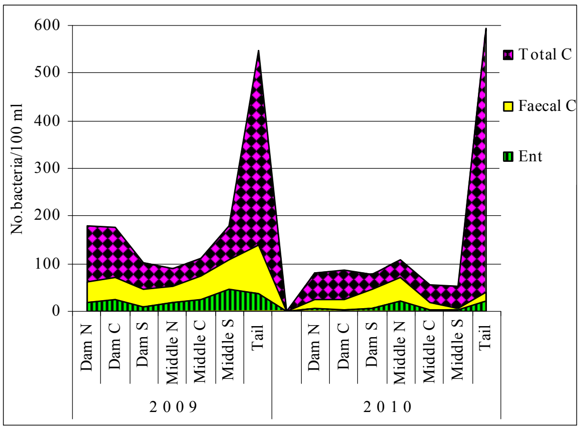

Figure 3. Distribution of the annual average of the sanitary bacteria in Văliug Lake (Total C = total coliforms; Faecal C = faecal coliforms; Ent = Enterococcus)

As for the lake Secu and for Văliug lower values were observed for all bacterial indicators in 2010. The greatest density for lake Secu is recorded at the sampling point in the middle of the lake, the southern part, the area with the most intense tourist activity.

Taking into question the southern shore of Lake Secu beach, with the most significant anthropogenic influence, the average values of total coliforms in 2009 reach 534.257 units, compared to only 232.95 in 2010. Aquatic environments with higher nutrient loadings possessed higher bacteria densities and lower bacteria community diversities [34].

For Lake Văliug (Fig. 3), the year 2010 also shows lower densities of bacterial sanitary indicators, but the annual maximums are recorded in the tail of the lake, where the Bârzava river enters, indicating the presence of lower bacterial concentrations at the surface than in the deeper layers of water.

For Secu lake (Fig. 4) this fact is evident in the samples taken in 2009 for all groups of bacteria. More uniform values are found in 2010, especially for total coliforms. Lower values of the number of bacteria in the vicinity of the mirror lake is due to the "cid" effect of infrared and UV solar radiation.

The surface water is exposed to the sun rays action, which may cause a massive decrease in the number of microorganisms, not only in the layer just under the surface but also at depths of 2.5-3 m [24].

The increase of the bacteria number with the depths may be determined by the effect of the sedimentation of solid particles. Through sedimentation, the solid particles draw with them the bacteria to the deeper layers, their number therefore decreasing in the surface zones (Fig. 5). Therefore the ability of bacteria to stay loosely associated with discrete sources of nutrients could be advantageous, by enabling bacteria to benefit from transient microenvironments and move on once the nutrient source has been depleted. Localised discrete sources of nutrients may explain the reason for chemotaxis in a turbulent environment [1, 9, 25].

Comparing the charts, we found remarkable similarities, being no important differences of the percentual variation (Fig. 6 and Fig. 7). In 2010, total coliforms had a higher percentage value of 72%, compared to 2009, when they had a smaller share, of

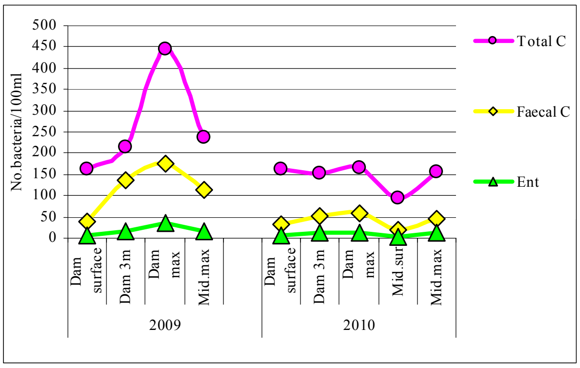

Figure 4. Vertical distributions of numerical bacterial density in Secu Lake (Total C = total coliforms; Faecal C = faecal coliforms; Ent = Enterococcus)

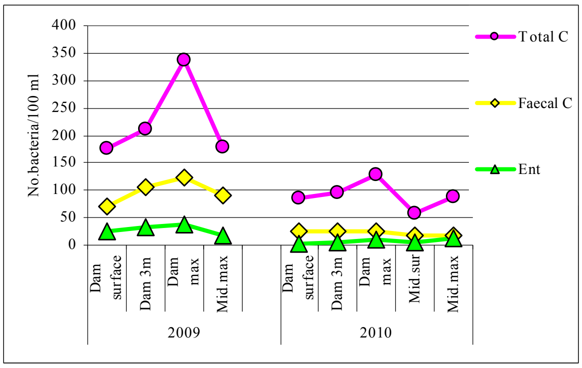

Figure 5. Vertical distribution of numerical bacterial density in Văliug Lake (Total C = total coliforms; Faecal C = faecal coliforms; Ent = Enterococcus)

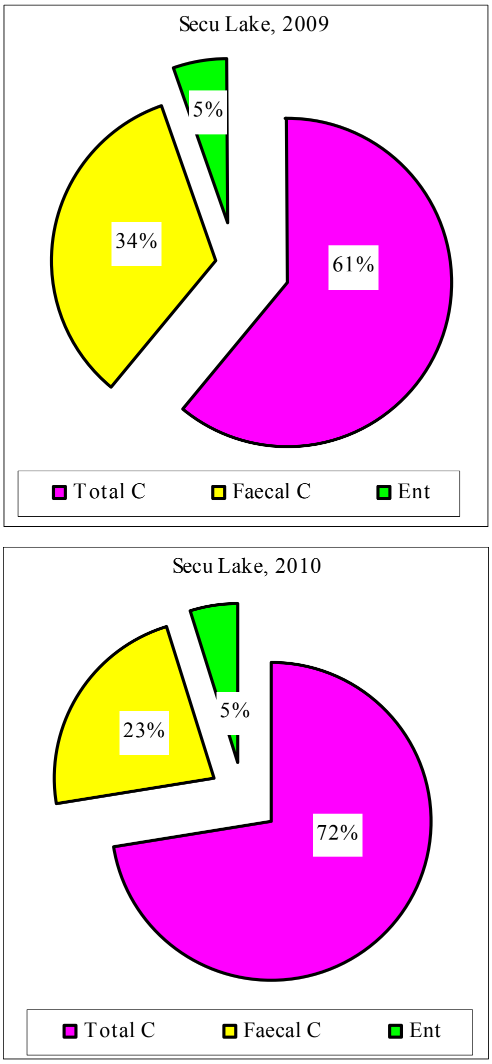

Figure 6. Percentage (%) of the sanitary bacteria in Secu waters (Total C = total coliforms; Faecal C = faecal coliforms; Ent = Enterococcus)

61%. The faecal coliformi certifying a faecal pollution had a decreasing percentage reaching 23% in 2010, compared to 34% registered in 2009. The faecal enterococci, certifying a recent faecal and massive pollution, remained at the same rate of 5%.

Analyzing the same parameter for Lake Văliug it appears similar, that the total coliform

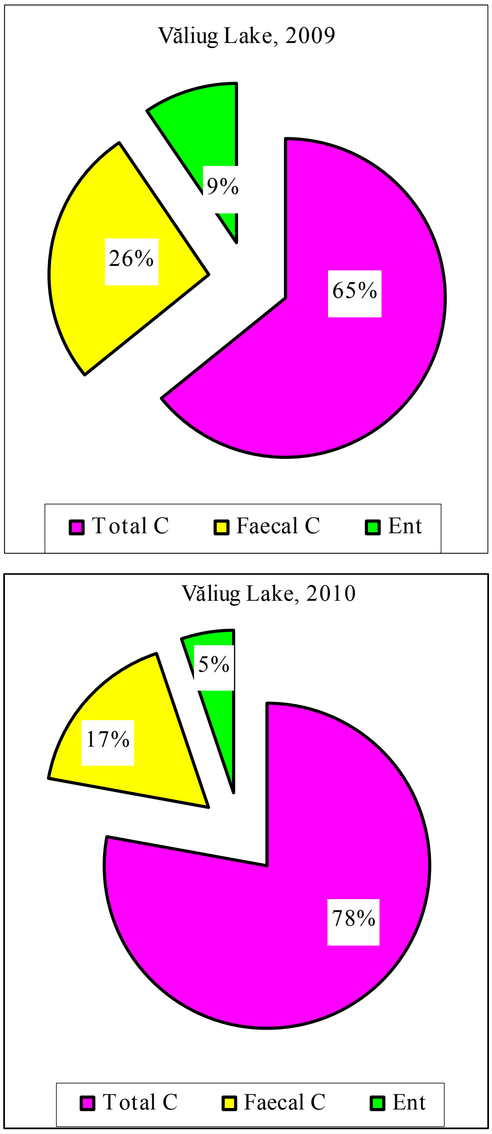

Figure 7. Percentage (%) of the sanitary bacteria in Văliug waters (Total C = total coliforms; Faecal C = faecal coliforms; Ent = Enterococcus)

bacteria were the largest group – of 65% in 2009 and 78% in 2010. Faecal coliform bacteria showed a higher percentage in 2009, that is 23% compared to 17% in 2010. Another good thing is the decrease of enterococci in 2010 from 9% to 5%, which indicates a reduction of the recent faecal pollution.

Bacterial communities were substantially diverse in the same season [6, 7]. Taking into question the anthropic areas of the lakes, that are the Southern shore of Lake Secu (Fig. 8) and the Eastern shore of Lake Văliug (Fig. 9), the seasonal distribution indicates high levels of sanitary bacteria, especially in summer.

The influence of anthropic pollution reaches the highest level in this season, the intake of organic matter includes also high values of other factors favorable for eutrophication (nitrogen, phosphorus, phytoplankton biomass, etc).

One of the primary goals of water treatment is the reduction of natural organic matter to levels that will not promote the regrowth of bacteria during distribution [16, 20, 21, 28, 30, 32].

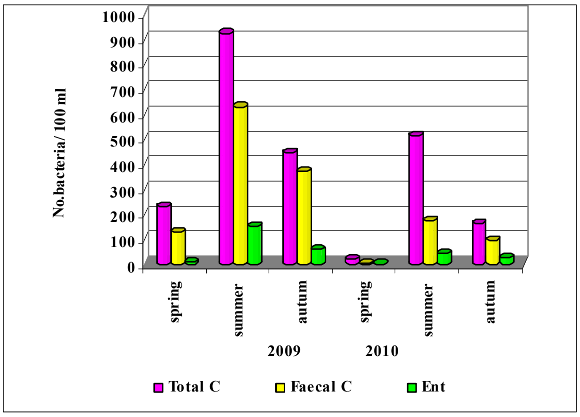

Figure 8. Sesonal distributions, middle South border (beach) from Secu Lake. (Total C = total coliforms; Faecal C = faecal coliforms; Ent = Enterococcus)

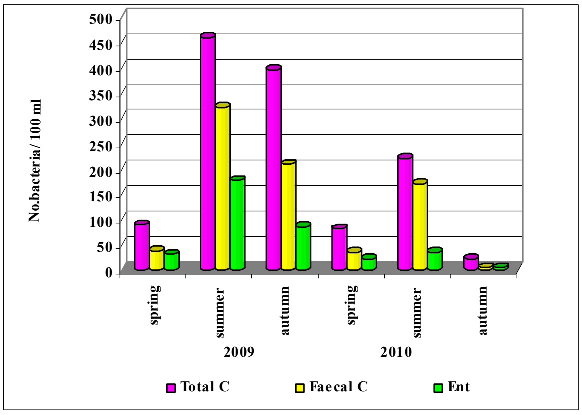

Figure 9. Sesonal distribution, middle East border (anthropic) from Văliug Lake (Total C = total coliforms; Faecal C = faecal coliforms; Ent = Enterococcus).

DISCUSSION

The indicator bacteria were present in most of the collection points in relatively low densities. In the group of studied bacteria, the total coliforms showed the highest values compared to other sanitary indicators, in all sampling points. The faecal enterococci presented the lowest values, even undetectable in some samples.

The limits for the numerical variation of sanitary bacteria were quite small, both for Secu and for Văliug Lake water. Drinking water is not sterile, and contains a multitude of microorganisms that have the potential to grow in a system [8, 10].

The vertical distribution indicates an increase of the bacterial density with the water depth. In deeper lake water we recorded higher densities compared to the surface. It was found in this case too, a more important development of the sanitary bacteria in deeper water layers, due to the accessibility to organic materials [13, 18]. The discharges from the human activity have a significant contribution for feeding the bacteria with nutrients.

The percentage variation established between the three main types of bacteria indicates a large proportion of total coliform bacteria of 61% in 2009 for Secu to 75% faecal coliforms for Văliug in 2010. Faecal coliforms have a smaller share ranging from 17% to Văliug in 2010 and 34% for Secu in 2009. The faecal enterococci were found in small proportions.

The horizontal spatial interpretation indicates numerical fluctuations. For Secu dam, there is a higher numerical bacterial distribution in the lake tail water and on the southern shore where the human activity is intense (road, beach, pensions). At Văliug, the highest values for the density of sanitary bacteria is recorded in the water of the lake tail and on the eastern shore, where many recreational building were constructed. Bacteria are a key component of the detrital microbial community because of their rapid colonization and high metabolic activity in association with detrital material [3].

The seasonal distribution showed an important increase of bacteria density in the hot season, for all analysed points, with peak-values in July and August. The direct proportionality temperature/microorganisms take to high bacterial density, both for Secu Lake and for Văliug Lake in the months with high temperatures, along with the contribution of organic matter caused by the human presence. The temperature and the substances dissolved in water have a major role in the development of microorganisms, influencing numerical values in the four seasons [2]. Parameters characterizing bacterial biomass and metabolic activity are compared with phytoplankton biomass and daily primary production rates throughout the year [23].

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