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Monitoring and Water Quality Assessment of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria

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Abstract: **A comparison study of water quality among different points/regions of Burgas Lake (Vaya Lake) in the Black Sea, region of Republic of Bulgaria, was undertaken. Dynamics of the water quality parameters in four seasons were investigated. Several water samples were collected from three regions of the lake near industrial and human activity areas. The samples were taken approximately 10-20 meters from the lake line, where the depth was 0.5-1.0 meter. Various tests were conducted to identify the levels of inorganic substances and physico-chemical parameters. The purpose of this research is to identify the changes in the ecological state of the lake, to identify trends in water quality, to specify the influence degree of the pollutants (chemical and biological) over the biodiversity of the lake and eventual use for recreational purposes. Based on the analyzed data, the pH was relatively basic, where it ranged between 8.1 and 5 with respect to all three points of sampling (North, Centre and South) of the lake. Conductivity ritched up to 3,110 µs/cm in fall season for Northern point of the lake while the minimum recorded conductivity was 971 µs/cm for central point of the lake in the spring time. Total insoluble solids' recorded was 229 mg.Dm^{-3} in summer time for northern and the lowest value was 8.00 mg.Dm^{-3} for southern point of collection. Many other substances involving Cr^{2+}, P, Fe^{3+}, Cu^{2+}, NO_3^- and others including heavy metals for the sediment. BOD, COD, microbial cells concentration, Nitrogen with its different state as well as saturated Oxygen were also analysed to determine the impact of human, industrial activities on water quality during four seasons of the year. Some of the data collected for such parameters have showed low concentrations which is an indicator for desirable level of pollution.**

Keywords: **Water quality, assessment, monitoring, physico-chemical parameters, Vaya Lake, Black sea.**

I. INTRODUCTION

The Burgas Lakes or Vaya Lake is a lake located in the Bulgarian city of Burgas in the region of the Black Sea. The lakes' total area (including swamps, marshes, ponds and other reservoirs) amounts to 95 km², of which 33.30 km². Burgas Lake is economic important, used to obtain sea salt and curative mud, as well as to supply the local economy with fresh water, port and tourism. The lake is located in a strategic location in which directly connected with Black Sea and in fact black sea has connection with Mediterranean Sea/basin from Turkey side. Figures 1-5 show the strategic location of the stated lake in the world. Figure 6 shows the area where study is done; A dynamic of the water quality parameters of Lake Vaya (Bugras Lake) in Burgas were investigated in four seasons of Summer (August-November), Fall (October-December), Winter (December-February) and Spring (February-April) at three important point of North (1), Centre (2) and South (3). At the Northern point, city's affluent discharged with several human activities, industrial activities are near to point 2 (Centre point) and Southern point (3) were investigated since it is far from those two matters.

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Fig.1 Study Area, general view of Black Sea and Mediterranean basin (Sea).

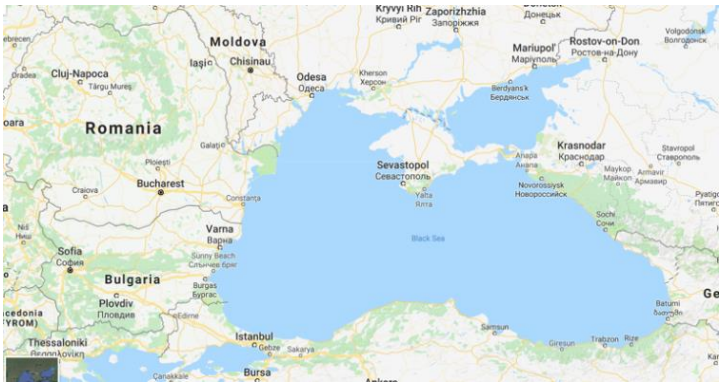

Fig. 2 Study Area, Black Sea and surrounding countries.

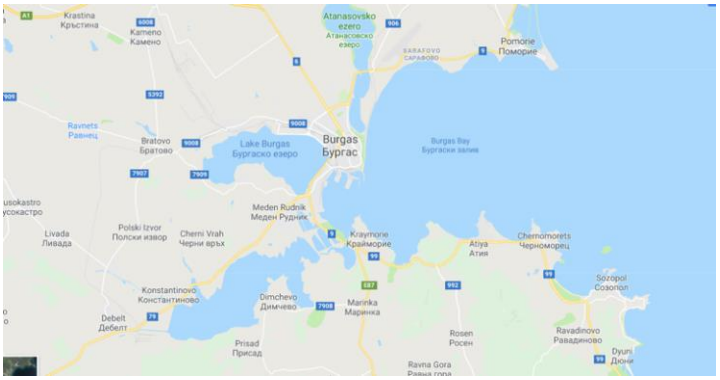

Fig. 3 Study Area, Lake of Burgas (Vaya Lake) in the Region of Black Sea, Burgas, Bulgaria.

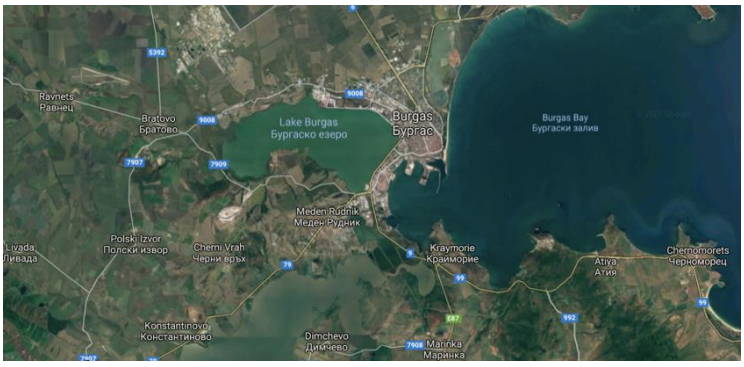

Fig. 4 Study Area, Lake of Burgas (Vaya Lake) in the Region of Black Sea, Burgas, Bulgaria.

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Fig. 5 Study Area, Lake of Burgas (Vaya Lake) Burgas, Bulgaria.

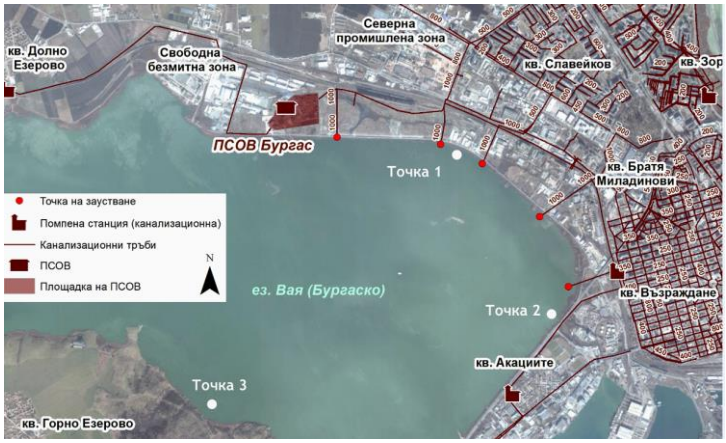

Fig. 6 Study Area North (1), Centre (2) and South (3), Lake of Burgas (Vaya Lake) in the Region of Black Sea, Burgas, Bulgaria.

II. MATERIALS AND METHODS

Chemicals, reagents used for water analysis experiment were of analytical grade.

Sample collection, lake water samples were collected from three points: North (1), Centre (2) and South (3) in the lake Vaya (Burgas Lake). Samples were collected during Summer, Fall, Winter and Spring seasons. All samples were taken 8m away from the shore at a depth of 1.0 m. Sediment samples are collected at a depth of 2.0 m and collected water were twice in a year since the changes of the sediment parameters are limited in a year-round (Fig. 3). Samples were then analyzed within one week from the time of collection. Water samples collected were subjected to:

a) Physico-Chemical test: pH, electrical conductivity, insoluble Solids.

b) Chemical (Inorganic substances/elements) analysis: Boron (B), Phosphorus (P), Iron (Fe), Aluminum (Al), Silicon (Si), Chromium (Cr), Manganese (Mn), Nickel (Ni), Cobalt (Co), Cupper (Cu), Zinc (Zn), Arsenic (As), Selenium (Se), Cadmium (Cd), Caesium (Cs), Barium (Ba) and Lead (Pb).

c) Pollution indicators such as BOD and COD, Nitrogen and total Nitrogen, Nitrate, Nitrite, Microbial cells concentration and Saturated Oxygen concentration.

III. RESULTS AND ANALYSIS

The data of water quality and sediment part of Vaya lake (Burgas Lake) in several points during the year (four seasons) were studied and tabulated in table 1-4. Figures from 7-16 are presenting some other physical parameters as well as pollution indictors. The nature of the lake, its strategic place, as well as habitat destruction, pesticide and heavy metal accumulation, nutrient loading, sedimentation, runoff and related impacts of man's activities are all taken in consideration during the study.

There are several industries exist near to point 1 (north point), in the other hands, at point 2 (central point), there are several attractions, beach, human activities are placed. Those two areas are focused in the study due to its activity rather than point 3 (south point) since there is no much activity there. Sediment analysis were taken from the bottom (depth 2 m) of the lake at random places searching for the heavy metal values and analysis. A number of these current and proposed developments are within several meters of this study and are likely to directly affect sedimentation, or indirectly through modification of near shore water movement and large-scale changes in lake composition. It is possible that these direct and indirect impacts may inhibit or even eliminate the natural exchange with the black sea since the lake Vaya is connected with the black sea.

Characterization of sea water, the results of water studies different points of Burgas Lake (Vaya Lake) in the Black Sea, region of Republic of Bulgaria are listed in tables 1-3 and sediments analysis listed in table 4. Various samples were collected few meters away from the shore (10 m) at 1.0 m and 12.0 m depth for the sediment samples. Several parameters as well as pollution indicator test results are shown and illustrated in charts Figures 7-18.

With respect to insoluble substances concentration, in general, it found to be higher in summer time with max value retched at 229 $Mg.Dm^{-3}$. This was seen at point 1 of the lake (Northern point) (Fig. 7) and the maximum conductivity value recorded was 3,110 μS at point 1 (northern point) as well and this is noticed for the other points too especially in month October-November of the year. Conductivity value is considered a good indicator of existing of excess species in water in fact once studied beside other parameters shall give us a clear correlation and results for both quantitative and qualitative idea of the water and elements presence (Fig. 8). The value of BOD found to be 49 $Mg.Dm^{-3}$ in Summer season (August) for the central point (point 2) and this might be due to human activities and attraction events during the summer time for Burgas city and in fact for the lake (Fig. 9) while is found to be low in winter time (3.0 $Mg.Dm^{-3}$) average for three point of collection). The chart of COD analysis has a regular trend in which the average values show low (spring), high (summer) and very low (during the other months of the year) 95.0, 325.0, 30.0 $Mg.Dm^{-3}$ respectively. The trend is considered logic and normal for the chemical process since it is represent the organic compounds that are oxidized at high temperature and in the presence of a strong oxidizing agent (Fig. 10). Saturated Oxygen of the entire lake is high in fall, winter and summer (Av 10.21 $Mg.Dm^{-3}$) but low in the spring with average value equal to 60 $Mg.Dm^{-3}$ (Fig. 11).

Moreover, microbial cells found to be high in fall with max value equal to 4,600.03 $CFU.cm^{-3}$ especially at point 1 and about 3,900 $CFU.cm^{-3}$ at central point (Fig. 12).

The pH value 7.4-8 in average standard which indicates a basic environment which can be one of the reasons that may lead to higher ammonia and other fragments. The analysis of total nitrogen and nitrogen as $N\text{-}NH_4$, $N\text{-}NO_3$, are also analyzed and presented in chart in figures 15-17. In general, the value of total nitrogen concentration varied from 0.40 $mg.Dm^{-3}$ (in the spring) to average 2.7 $mg.Dm^{-3}$ in summer time for all three points of collection. The concentration of $N\text{-}NH_4$ max is recorded in summer (September time) with value equal to 2.11 $mg.Dm^{-3}$ (average value) for all three points and low in the spring (0.21 $mg.Dm^{-3}$) that indicates level of human activities is higher in September of the year round and low trend towards fall and winter resulted that the concentration of nitrogen as $N\text{-}NO_3$ and $N\text{-}NO_2$ reached the max value in the entire lake in fall (October and November) and the behavior is shown in figure 14 and 15 in this work.

The lowest phosphorus concentration value (as $P\text{-}PO_4$) (near to zero) analysis found at point 2 (centre) in the spring and high value recorded was 0.31 $mg.Dm^{-3}$at south point (point 3). Moreover, several water samples were collected for inorganic substances analysis the value of each element for all three points of collection are tabulated in table 1-3. Sediment analysis values can be found in table 4.

As we have noticed parameter analysis were taken in a limited period of time for south point (3) so that this point is far from industrialized area or human activities indicating a non-polluted site for that part of the lake. This is a good sign of well regulated and managed sites facilities leading to desirable level of pollutants.

The lake water quality in general is desirable[15]. To our knowledge, this project is one of the first studies to give a general overview of the water quality for those three points of collections Northern, central and southern points of the lake Vaya (Bugas Lake).

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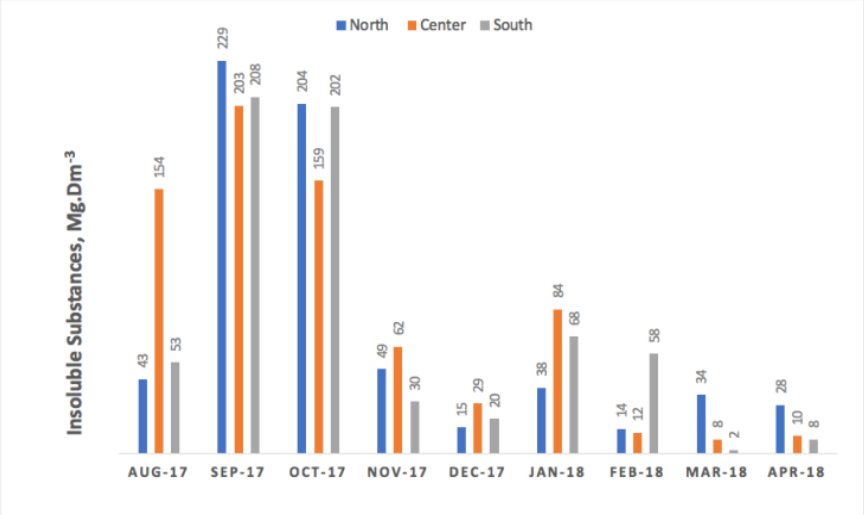

Figure 7: Comparison analysis of Insoluble Substances Concentration (mg/l) of North, Centre and South points of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

Figure 8: Comparison analysis of Conductivity value (µS) of North, Centre and South points of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

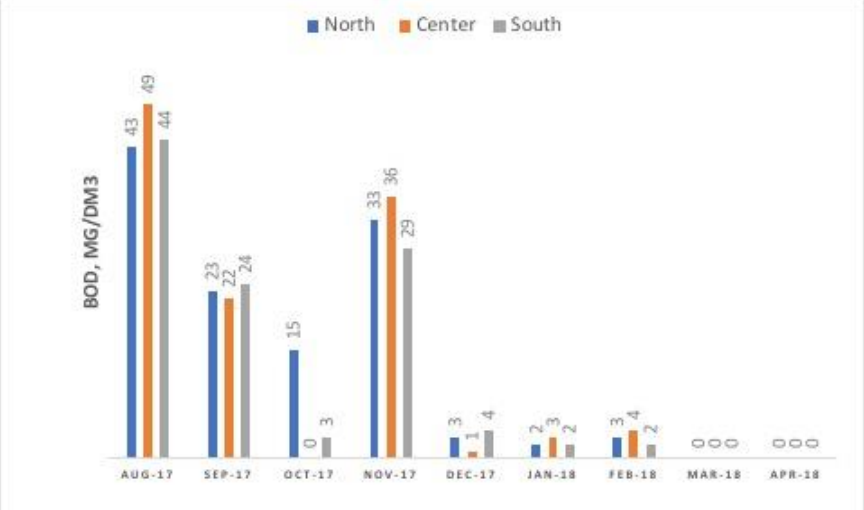

Figure 9: Comparison analysis of Bio-Oxygen Demand (BOD) (mg/l) of North, Centre and South points of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

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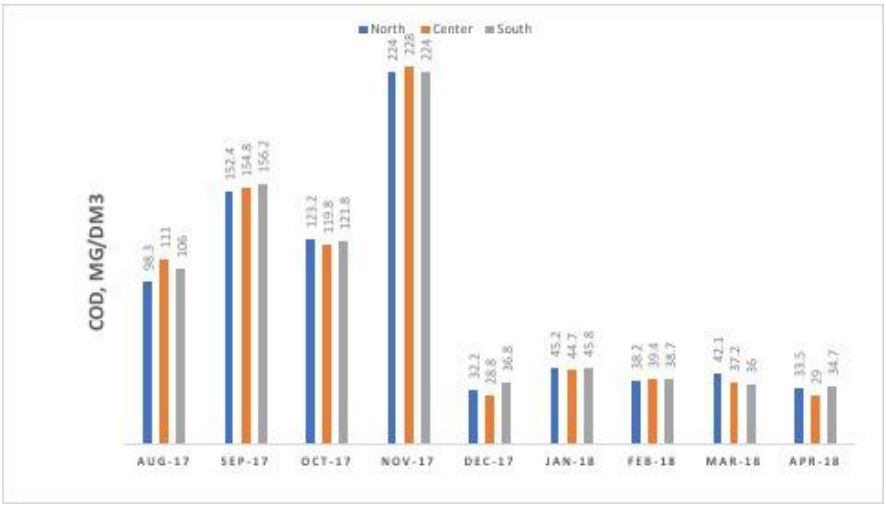

Figure 10: Comparison analysis of Chemical Oxygen Demand (COD) (mg/l) of North, Centre and South points of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

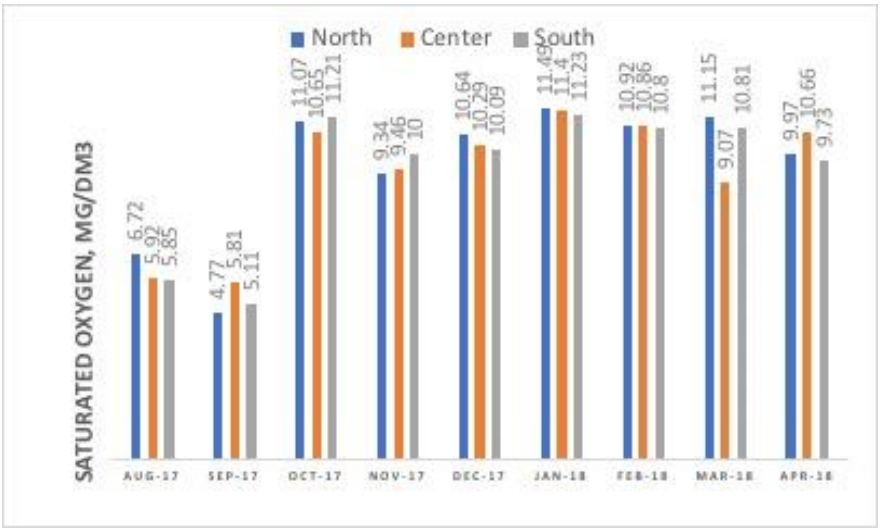

Figure 11: Comparison analysis of Saturated Oxygen (mg/l) of North, Centre and South points of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

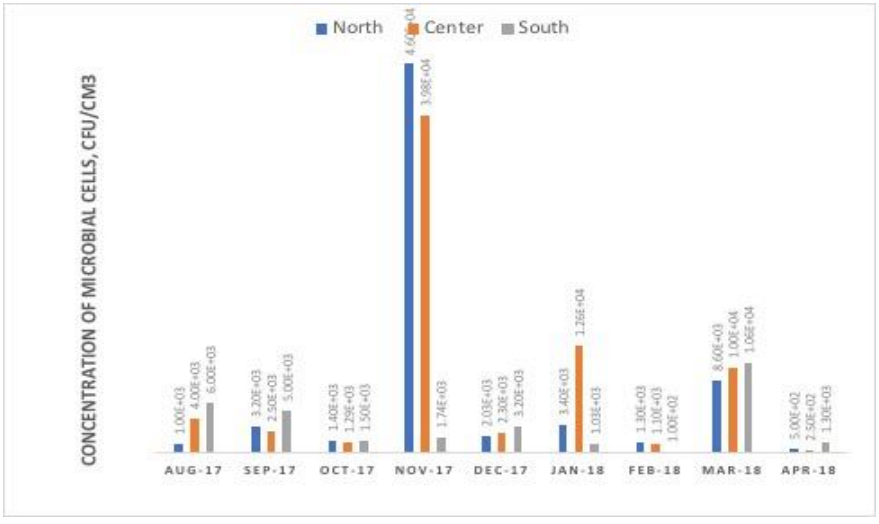

Figure 12: Comparison analysis of Microbial Cells Concentration (CFU/l) of North, Centre and South points of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

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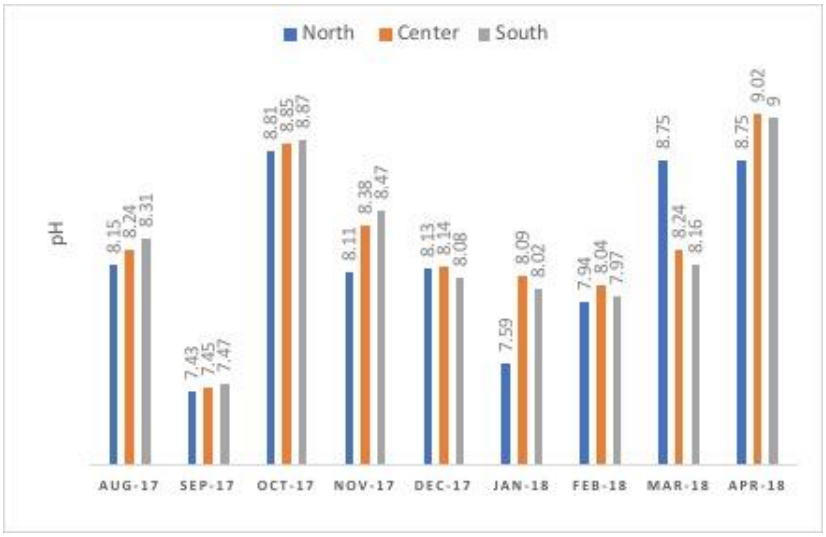

Figure 13: Comparison analysis of pH Value of North, Centre and South points of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

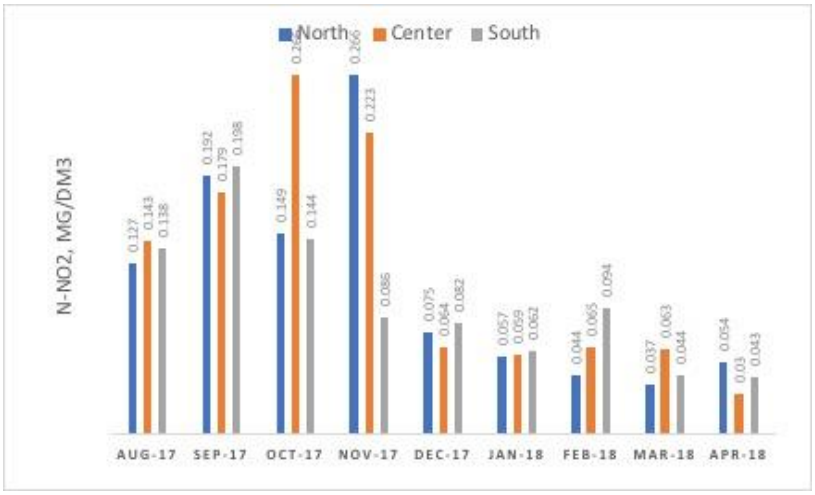

Figure 14: Comparison analysis of Nitrogen as N-NO_2 Concentration (mg/l) of North, Centre and South points of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

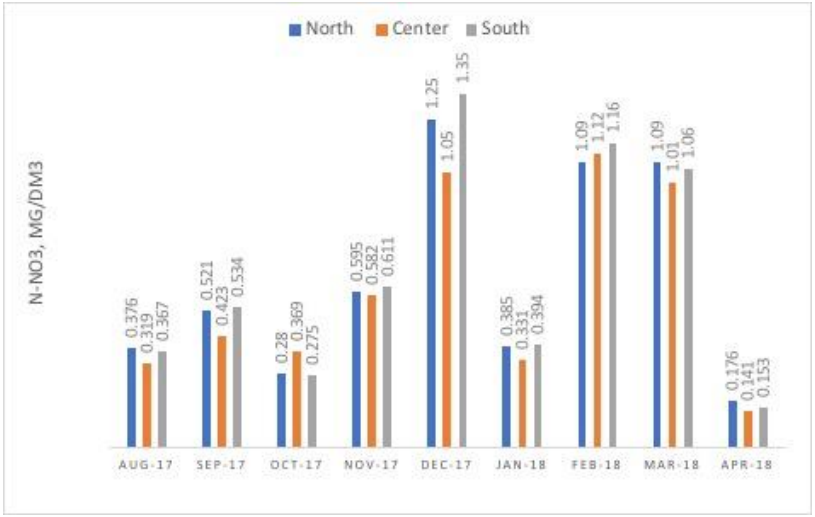

Figure 15: Comparison analysis of Nitrogen as N-NO_3 Concentration (mg/l) of North, Centre and South points of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

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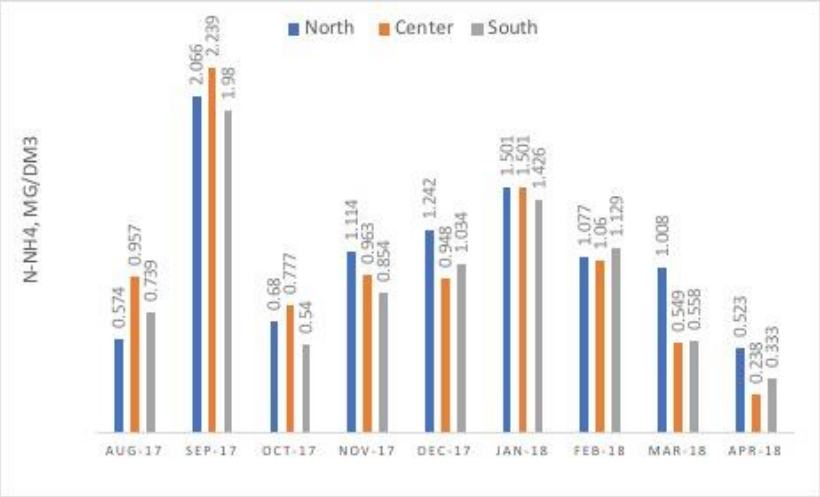

Figure 16: Comparison analysis of Nitrogen as N-NH_4 Concentration (mg/l) of North, Centre and South points of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

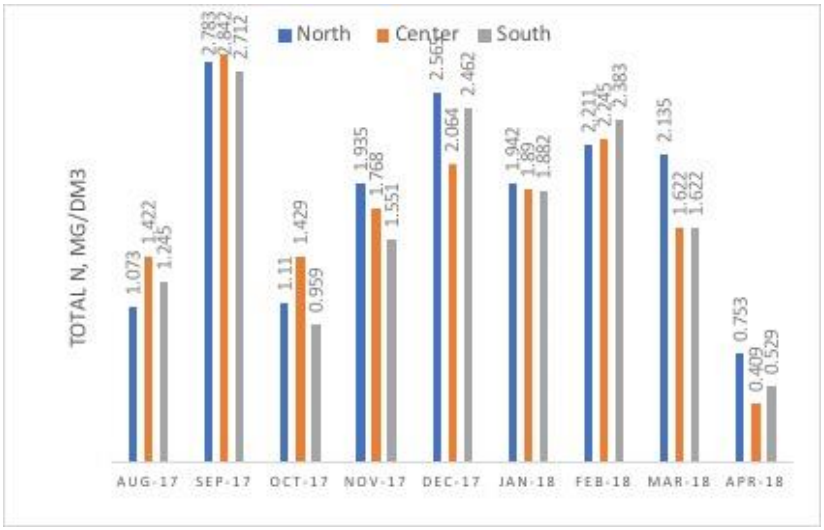

Figure 17: Comparison analysis of Total Nitrogen Concentration (mg/l) of North, Centre and South points of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

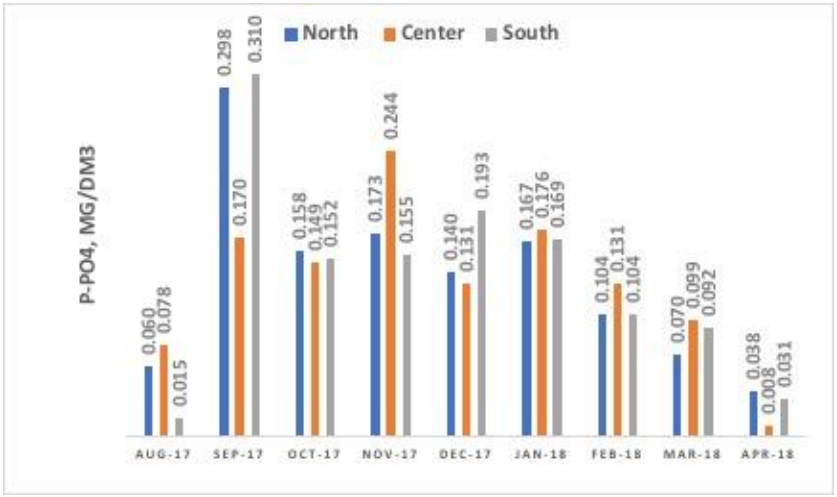

Figure 18: Comparison analysis of Phosphorus as P-PO_4 Concentration (mg/l) of North, Centre and South points of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

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Table 1: Physico-Chemical properties and concentrations (ppb) of selected inorganic substances at North point (1) of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria (at 25 ^{O}C), shore depth = 1.0 m.

Test Name	Concentration (ppb)					
	Aug-17	Sep-17	Oct-17	Jan-18	Feb-18	Mar-18
B	400.828	383.162		242.034	215.882	23.453
Al	9.473	319.086	*	105.719	187.997	40.724
Si	10,856.036	15,191.123		13,690.729	13,871.115	3,551.817
P	158.361	260.142	74.267	133.033	83.919	57.696
Cr	*	20.952	1.089	104.069	33.026	*
Mn	2.967	25.722	8.642	17.612	13.298	3.364
Fe	141.793	506.681	219.875	1456.411	738.881	93.241
Ni (I)	4.287	32.743	3.908	91.488	43.327	*
Co	*	1.941	0.964	4.302	1.594	*
Ni (II)			4.233	155.940	52.335	*
Cu (I)			6.785	23.252	16.308	20.683
Zn	11.258	52.634	2.419	21.129	18.141	30.356
Cu (II)	3.390	39.499	1.464	20.097	14.083	18.385
As	13.453	25.041	5.887	3.437	3.683	2.606
Se (I)				0.983	0.758	0.618
Se (II)			6.598	3.161	3.151	1.679
Cd (I)			0.156	0.200	0.093	0.053
Cd (II)	0.282	1.909	0.176	0.223	0.114	0.233
Cs			0.020	0.091	0.070	*
Ba			30.772	34.843	35.675	24.531
Ba	35.067	19.851	18.549	28.247	26.833	25.900
Pb	2.305	15.498	0.391	3.534	0.636	0.563
* below the limit of quantification						

Table 2: Physico-Chemical properties and concentrations (ppb) of selected inorganic substances at Centre point (2) of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria (at 25 ^{O}C), shore depth = 1.0 m.

Test Name	Concentration (ppb)					
	Aug-17	Sep-17	Oct-17	Jan-18	Feb-18	Mar-18
B	286.522	361.015		212.105	228.295	12.421
Al	25.977	313.351	*	111.629	279.497	92.966
Si	7,437.643	13,991.310		14,898.469	15,537.019	3,718.760
P	105.174	313.016	83.257	125.145	146.505	108.378
Cr	38.612	14.530	0.669	90.922	119.813	*
Mn	6.721	32.361	6.843	20.590	24.663	18.097
Fe	229.769	489.842	207.408	1,340.119	1,544.475	156.217
Ni (I)	28.893	20.221	7.829	80.511	75.394	*
Co	*	1.749	0.966	3.864	4.731	0.017
Ni (II)			8.251	137.201	166.037	*
Cu (I)			7.485	24.526	17.320	16.043
Zn	15.623	36.964	5.243	19.044	10.250	26.228
Cu (II)	5.420	31.343	2.662	21.467	14.228	14.411
As	8.558	19.844	6.180	3.946	3.662	2.648
Se (I)				0.863	1.578	0.995
Se (II)			6.415	3.286	3.137	1.777
Cd (I)			0.490	0.160	0.121	0.035
Cd (II)	0.601	0.466	0.509	0.171	0.123	0.233
Cs			0.022	0.077	0.071	*
Ba (I)			32.030	35.962	48.311	22.271
Ba (II)	32.489	19.504	19.019	35.682	30.416	23.191
Pb	1.332	3.736	0.682	1.356	0.376	0.284
* below the limit of quantification						

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Table 3: Physico-Chemical properties and concentrations (ppb) of selected inorganic substances at South point (3) of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria (at 25 ^{O}C), shore depth = 1.0 m.

Test Name	Concentration (ppb)		
	Aug-2018	Feb-18	Mar-18
B	388.811	235.925	34.081
Al	9.968	439.962	93.762
Si	10,487.434	17,213.109	3,849.295
P	164.321	175.151	79.040
Cr	*	94.867	*
Mn	3.294	22.919	14.723
Fe	163.741	1338.987	170.005
Ni (I)	6.017	74.679	*
Co	*	4.066	0.049
Ni (II)		135.040	*
Cu (I)		19.373	12.717
Zn	15.352	14.481	24.973
Cu (II)	5.107	15.974	10.784
As	12.661	4.300	2.568
Se (I)		2.198	1.085
Se (II)		3.117	1.599
Cd (I)		0.127	0.069
Cd (II)	0.410	0.133	0.253
Cs		0.087	*
Ba (I)		51.971	21.741
Ba (II)	37.620	33.105	22.253
Pb	3.463	0.459	0.347
* below the limit of quantification			

Table 4: Heavy Metals analysis and concentrations (mg.Kg^{-1}) of the sediment at South point (3) of Burgas Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria (at 25 ^{O}C).

Metal Name	Concentration (mg.Kg^{-1})				
	Aug-17			Sep-17	Feb-18
	North (1)	Center (2)	South (3)	Center (2)	Center (2)
B	5.694	10.109	4.687	13.716	13.302
Al	8,409.078	8,753.159	4,466.645	88.807	6,632.090
Si	106.552	141.432	63.209	151.196	1,574.967
P	1,927.960	2,111.651	1,250.316	1,846.654	684.764
Cr	31.020	36.517	33.148	6.844	55.101
Mn	227.406	228.178	106.515	53.792	334.095
Fe	11,088.582	11,551.867	5,782.336	434.035	6,996.961
Ni	80.888	86.111	42.089	12.807	91.078
Co	15.604	18.150	8.012	0.587	8.675
Zn	28.089	30.036	18.774	78.855	58.864
Cu	29.413	29.475	16.294	21.726	31.597
As	6.833	13.505	4.250	8.785	1.834
Se	130.986	168.490	130.620	*	*
Cd	6.005	6.449	2.002	0.183	0.679
Ba	54.660	64.766	26.703	25.004	73.697
Pb	12.238	11.697	5.941	3.027	25.979
* below the limit of quantification					

IV. CONCLUSION

The aim of this project is to study the water quality and assessment of different points/regions of Burgas Lake (Vaya Lake) in the Black Sea, region of Republic of Bulgaria. Many Physico-Chemical parameters, pollution indicator tests such as BOD, COD nitrate and others for water samples taken at depth 1.0 m and 2.0 m for the sediment water collection were analyzed and managed. In general, we have found that the pH values were basic, conductivity, BOD, COD values were high especially in Summer time Saturated Oxygen was relatively same for the entire lake in four seasons while total

insoluble solids values were within normal range. Many inorganic and chemical parameters were at low concentrations despite the fact that the studied area is industrialized indicating a non-polluted site for lake. It seems to us (authors), this project is one of the first and latest studies to give a general assessment and of the water quality of Burgs Lake (Vaya Lake) in the Black Sea Region of Republic of Bulgaria.

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