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Research Article

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Biochemical approach to assess groundwater pollution by heavy metals pollutants and organics (case Reghaia Lake, Algeria)

Boussaid Khadidja*[1] and Chebouti–Meziou Nadjiba[2]

[1]Research Laboratory Sweet Technology, Valorisation, Physical-chemistry of Biological Materials and Biodiversity, M'Hamed Bougara University, 35000,Boumerdés , Algeria.
[2]National Office of Sanitation, Baraki, 16000, Alger. Algeria.

Contacts of Authors

* **To whom correspondence should be addressed: Boussaid Khadidja**

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Abstract

The article deals with the determination of the factors responsible for the degradation of the Reghaia nature reserve. The objective of this research was to evaluate the spatial variation of chemical pollutants including the accumulation of some heavy metals (Iron, Zinc, Copper, Cobalt, Cadmium, Silver, Nickel and Lead) in the water of Lake Reghaia, Algiers. The study was carried out on 64 water samples taken from Reghaia Lake. For physico-chemical parameters and for MTEs that have been assayed by atomic absorption spectrophotometry. On the chemical level, high levels of nitrates have been recorded in water between 4mg / l, 30mg / l and concerning the phosphate, it has a high content (5.7 mg / l). Surface waters have high levels of suspended solids. BOD_5 and COD are high, with COD / DBO_5 ratios well above 3, dissolved oxygen values do not comply with WHO standards with P = 0.000001. Water degradation is caused by the presence of latrines, piles of garbage, farms, draining of sanitation facilities in nature and especially in watercourses. Heavy metal pollution is significant and has been reported for Plomp (Pb), copper (Cu), iron (Fe) and cobalt (Co), which reached the high risk level ($p < 0.01$) especially upstream of the Reghaia Lake. And that the MTE contents vary irregularly from one station to another and from one depth to another. The results reveal that the waters of the Réghaia Lake are of very poor quality and the degradation of the ecosystem is more and more increased, to this effect a treatment is recommended.

Keywords: Biochemical parameters, BOD_5, COD, ETM, Lake of Reghaia, pollution.

Introduction

The increase in the urban population of the major African cities generates increasing food requirements, correlated with an increase in the production of organic materials such as urban waste (sewage sludge, domestic wastewater), livestock manure (manure, manure) and agro-industrial by-products [1]. The pollution of the aquatic environment by inorganic chemical and organic matter is resulting from pollutants out of sources of anthropogenic different has become a global concern [2]. Heavy metals pollution generated by landfill leachate has become increasingly concerned due to its potential impact on human health [3]. The accumulation of heavy metals can be a factor in the poisoning of some organizations that around her can be fatal [4-9]. The lake of Reghaia is a coastal area moist considered since a long time as a site of international importance, the last remnant of the old Mitidja, Is currently the single wet zone of the biogeographical region of the from Algiers classified at the international level Secretariat of the Ramsar Convention (RAMSER) [10]. The demographic growth brutal than are aware of the developing countries and their difficult economic conditions lead to an anarchic urbanization hardly controllable, The implantation and the development of the cities of Reghaia and Rouïba from industrial areas are one of the sources of water and soil contamination by heavy metals. This Pollution contains the major part of the heavy metals encountered at the level of the lake of Réghaia.

The toxicity of these substances is manifested, either immediately or after a delay after accumulation in the tissues of living organisms. It is because the human regulations not controlled have an impact on the quality of the water in these wet area due to the lack of infrastructure (For example, factories Water treatment) Which allows the appropriate treatment of domestic waste, municipal or industrial (particularly in the under-developed countries) [11]. Specific work has addressed the pollution of water resources in North Africa.

This work has revealed the presence of nitrates and heavy metals in groundwater and estimate that this pollution would come from the reuse of raw sewage in agriculture. El Asslouj et *al*., and Smahi et *al*., [12,13] noted that the concentrations of the elements considered of major pollutants and indicators of pollution are high in the wastewater and in groundwater. In Algeria other works have dealt the factors that affect the contamination of waters as those of Ehteshami et *al*., [14].

By against in Egypt Abedel-Fattah et *al*., [15] have estimated the effects of the accumulation of heavy metals are harmful in the irrigation water resulting from the proximity of the different activities of different waters: wastewater, artesian wells, and industrial activities. In Algeria, little work in this context have been realized. To this effect, the present study was undertaken to assess the levels of pollutants including the accumulation of a few heavy metals (Iron, Zinc, Copper, Cobalt, Cadmium Argen , Nickel, and Lead) in the water of Lake Reghaia .

Materials and Methods

Presentation of the study area: The wet area of Reghaia Lake has located 30 km from Algiers, on the northeastern boundary of the Mitidja, This Reserve covers an approximate surface area of 742 hectares. The lake has an area of 0.75 km2, length ¼ 2.5 km, and a 7 m depth **.**The lake has a surface area of approximately 100 ha, is at the following coordinates (3°20'4.63"E; 36°45'58.41"N and 3°19'59.81"E;36°46'41.95"N ; **Figure 1**) [16].

It is supplied by the famous Oued Reghaia ,in the watershed reaches 15 km² and by the Oued El Biar ,taking birth to the surroundings of the industrial zone of Rouiba, Reghaia, crosses a large part of the agricultural fields before pouring to the level of the lake according to some authors [10]. It exists grace to the outcrop of the sheet, An underground supply of the marsh.

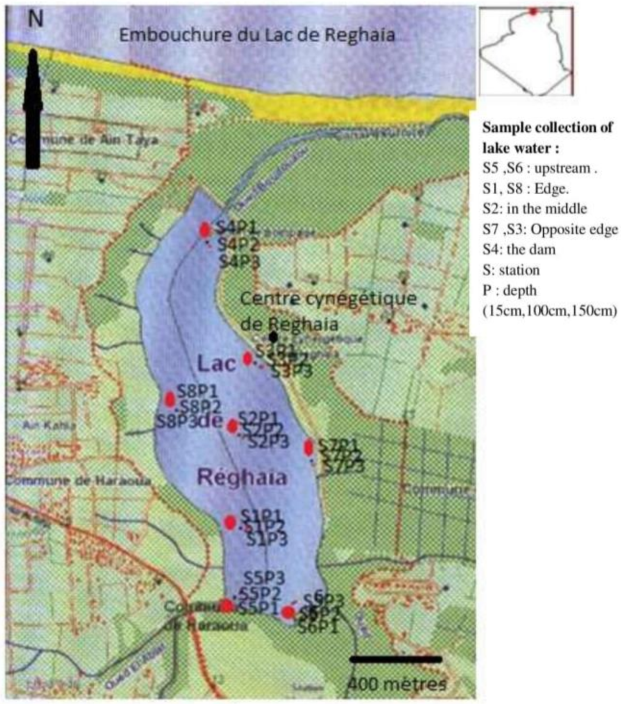

Figure 1. Map of the Lake of Reghaia and sampling locations. S5, S6 (upstream); S1, S8 (Edge); S2 (in the middle) S7, S3 (Opposite edge) S4 (the dam); S (station); P (depth) (15cm, 100cm, 150cm).

Sampling: The samples were taken using small boats, we have taken, at each point and at a depth of 15cm, 100 cm 150 cm. Either 500 ml of water for analysis of heavy metals, 1 liter for the measurement of BOD And 1 liter for physicochemical analyses. The bottles for the trace metal analyses were acidified with 2.5 ml concentrated HCl per liter.Finally, the samples were stored in a refrigerated cooler during transport to the laboratory where the analyses were carried out immediately. On-site water and air temperature, and GPS positioning were noted **(Table 1)**.

Table 1. The coordinates of the sampling stations.

Stations	Latitude	Longitude	Temperature
S1	36°45'58.41"N	3°20'4.63" E	16°
S2	36°46'10.57"N	3°20'7.27"E	15.5°
S3	36°46'23.52"N	3°20'7.15"E	15°
S4	36°46'41.95"N	3°19'59.81"E	15.5°
S5	36°45'47.61"N	3°20'7.47"E	15.4°
S6	36°45'45.76"N	3°20'12.22"E	15°
S7	36°46'9.07"N	3°20'20.01"E	15.1°
S8	36°46'16.36"N	3°19'53.55"E	15.5°

Study method: The physicochemical analyses were carried out at the Office of National Assessments (ONA) of Djelfa and concerning the element trace metal (MTE) were carried out at the level of the ONA of Baraki. The physicochemical parameters are monitored according to the technique of Rodier [17]. All manipulations in the laboratory were carried out in 2 hours after sample collection in the field **(Table 2)**.

Table2. Methodology of Physico-chemical parameters, pollution indicators, and MTE.

Parameters	Methods of measurement
PH	pH meter
Temperature	Thermometer
NO_3^-, NO_2^-, NH_4+, PO4 3-, DCO,	Colorimetric determination by spectrophotometer Hanna Instruments HI 83224 Water Test Spectrophotometer
SM	Method of centrifugation
BOD5	BOD meter
MTE(Fe, Cu, Cd, Co, Ni, Ag, Zn, Pb)	ICP Perker elner model AA400
Conductivity	Testers and analyzers pH, CE, RedOx, T°C sensION Testers and analyzers pH, CE, RedOx, T°C sensION
Redox potential **Dissolved Oxygen**	

Measurement of heavy metals in the water of Reghaia Lake: The heavy metals in the solution obtained were measured using the inductively coupled plasma optical emission spectrometer ICP Perker elner model AA400. Analyzes of the pollution parameters biochemical oxygen demand (BOD5) and chemical oxygen demand (COD) were carried out according to the methods described by Rodier [17].

Statistics: The current data are the mean values with a standard deviation of three replicates. , a simple correlation was calculated to study the relationship between the heavy metal content at different stations. The variance and significance of the differences between the concentrations of physicochemical parameter and heavy metals were analyzed using analysis of variance (ANOVA) (*: $p \leq 0.05$; **: $p \leq 0.01$; * **: $p \leq 0.001$).

Results and Discussions

The hydrochemical data show an intense macro-pollution in the waters of the Reghaia Lake. The evolutionary study of the average contents of the main parameters and indicators of pollution showed several important information.

Potential of hydrogen (pH) and conductivity: We note the neutral character of the sampling medium, given the values of pH obtained. The values of the pH measured in the whole of the stations indicate a slight difference (7.81-7.68) upstream is (7.71-7.51) in the middle, by against the dam is varied between (7.35-6.75) But, pH variations are observed in the depth of the other the pH values are higher in summer period that those periods of rainfall. While the relatively high values of the conductivities (348 -497 µS · cm $^{-1}$) In the sites S1 and S2 have presented the highest values either respectively (624 and 569 µS · cm $^{-1}$) This indicates the character highly mineralized water from the lake. These preliminary results can, therefore, introduce the presence of pollutants minerals because this elevation of the conductivity is not associated with an acidity important **(Table 3)**.

Dissolved oxygen: The dissolved oxygen values measured in all the stations indicate a large difference between the different depths S1P1, S1P2 and S1P3 are (5.34, 0.15 and 0.9 mg/L, respective menu the dissolved oxygen values do not comply with WHO standards with P= 0.000001. However, during the summer months (**Figure 2**), poor oxygenation of the water, marks the intensity of degradation processes and the influence of waste water discharges. Among the causes of decreased oxygen dissolved in lake human activities around bodies of water can have a great influence on the concentration of dissolved oxygen in the water [18]. This situation reflects the importance of the influence of wastewater during the summer and rainwater during periods of precipitation. The results of this study are of poor quality where pollution is important. On the other hand, the results obtained by Yong-Hui et *al.*, [19] and Jessica Badillo-Camacho *et al.*, [20].

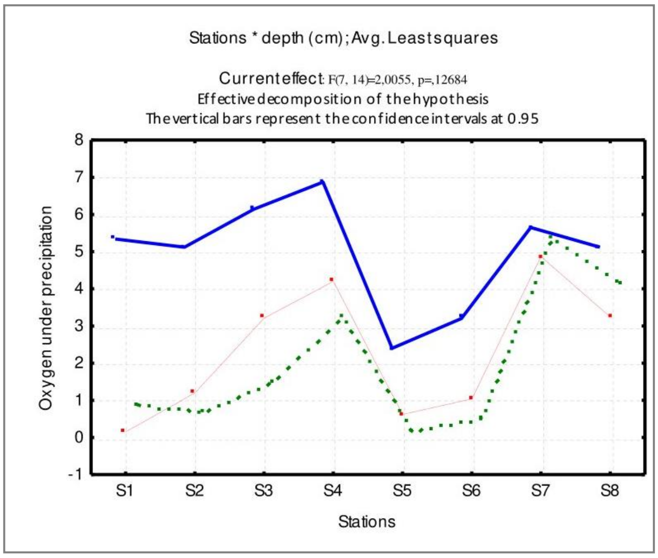

Figure 2. Spatial variation of the dissolved oxygen in a period of precipitation in mg/L in Reghaia Lake

Table 3. Descriptive statistics of ten variables measured in the waters of eight sites of Lake Réghaia.

Stations	depth (cm)	COD	$PO4^{3-}$	NO−3	T°	PH during precipitation	Dissolved Oxygen	conductivity µS
S1	P1	470	2.1	30	16	6.51	5.34	346
S1	P2	400	3.1	25	15	6.57	0.15	194
S1	P3	404.33	7.5	28.6	14.9	6.62	0.9	257
S2	P1	470	1.9	9.3	16	6.98	5.12	162.5
S2	P2	477	2.1	8	15.4	7.04	1.2	162.9
S2	P3	395	2.8	8.7	15.6	7.02	0.68	163
S3	P1	178	0.1	8.1	17.8	7.43	6.14	163.8
S3	P2	157	1.43	9	18	7.46	3.21	164.8
S3	P3	402	5.7	6.4	18	7.54	1.5	164.1
S4	P1	131	0.7	8.3	17.9	7.37	6.87	155.2
S4	P2	170	1.8	7	17	7.16	4.2	158.9
S4	P3	40	4	4	16.5	6.83	3.24	160.5
S5	P1	301	1.5	41.7	16.2	7.27	2.4	241
S5	P2	314	2.7	43.5	15	7.38	0.62	235
S5	P3	580	4.8	32.7	14	7.31	0.15	245
S6	P1	296	1.9	33.1	15.1	7.37	3.2	324
S6	P2	330.33	3.2	28.9	14.5	7.47	1.04	251
S6	P3	266	3.4	23.1	14	7.36	0.51	236
S7	P1	88	0.4	10.5	16	7.11	5.65	174
S7	P2	80.33	2.1	15.1	16	7.14	4.87	178.3
S7	P3	77	8.9	18.4	15.8	7.16	5.38	182.4
S8	P1	88.33	0.8	12	15.3	7.35	5.12	152.3
S8	P2	79	1.5	10.8	15	7.3	3.24	158
S8	P3	87.66	3.3	8.6	15	7.41	4.17	162,4
Average		261.749	2.82	17.95	15.83	7.17	0.54	199.67
Minimum		102	0.1	4	14	6.5	0.1	152.3
Maximum		109	8.9	43.5	18	7.54	1.32	6.46

On the other hand, the results obtained by Yong-Hui et *al.* [19] and Badillo-Camacho et *al.*, [20], Higher levels are observed in all stations Reaching the maximum value of 30 mg / L in station S1P1 (On the surface) during the month of March, the nitrate values far exceed the WHO standards with P = 0.003660. These high concentrations observed particularly on the surface near the mouths of the oued El Abiar and Oued Reghaia In relation to significant water inputs during this period. Compared with the results of the previous work, our results support those obtained by Yong-Hui et *al.*, and Badillo-Camacho *et al*., [19-20] but at the same time reveal high values.

In general, the nitrite contents obtained are relatively low. These levels vary between a minimum value of the order 0.051mg / L observed in the station S1P2 during the month of May, And a maximum concentration of the order 0.284 mg / L reported at the S2P1 station during the month of May 2016. The same results were demonstrated in the other regions studied. In these areas, the main sources of nitrate contamination are domestic fertilizers and sewage.

Nitrate: With the highest values being measured at stations near the Reghaia and El Abiar S1, S2, S3 wadis, which are respectively 25.3, 42.1 and 58.4 mg / L during the month of May 2016. **Table 3** shows that the significant increase was observed from P1 to P3, 0.063, 20.3 and 77.1 mg/L respectively, Due to a significant nitrogen pollution resulting from a reduction of ammonium nitrates and nitrites [21]. The highest levels of nitrate (NO−3) in the various sampling stations are particularly localized at the stations receiving the inputs from the wadis. These areas are generally enriched in these two nitrogen compounds by the discharge of domestic and industrial wastewater.

Orthophosphate: The examination of the **Table 3** and **Figure 3** shows that the phosphate ($PO4^{3-}$) contents vary from one station to another**.** The maximum value is 7.5 mg / L recorded in station S1P3 during the month of March 2016. The minimum value is recorded in station S8P1 (0.07 mg/L). Orthophosphate values well exceed WHO standards with P = 0.000002. The phosphate level is too high, this favors overproduction of the algae which decompose thereafter using oxygen from the medium; it is responsible for the bad odors and the eutrophication of the lakes.

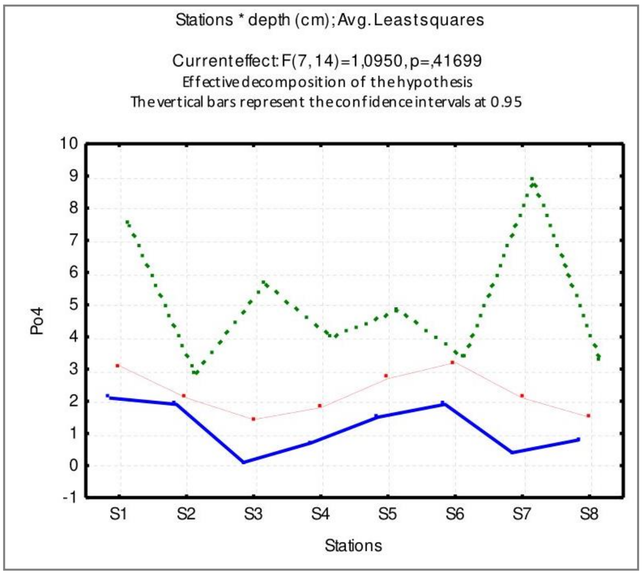

Figure 3. Spatial variation in the concentrations of PO_4^{3-} of Reghaia Lake.

The presence of phosphates in natural waters at concentrations greater than 0.1 or 0.2 mg / l is indicative of pollution by sewage containing organic phosphates and synthetic detergents as well as runoff. Nisbet and Michel (2011) [22] and Afri-Mehennaoui [23] admit the limit of 0.3 mg/l for running water, beyond which it may retain a marked eutrophication character and risks of various nuisances. Compared with the work of Yong-Hui *et al.*, [19] our results confirm them. Indeed, the waters of Reghaia Lake are characterized by high levels of phosphates, reflecting a net pollution.

Suspended materials (SM): The examination of the **Table 3** and of **Figure 4** shows that the SM values ranged from 623.54 to 46.66 mg / L from the inlet to the outlet. This fall in SM was due to decanting the small particles. SM values were relatively high and well above WHO standards [24]; With a P = 0.000084. Thus, such a result could be linked to the very significant seasonal variations at these stations. Also, during rain events, run by the transport of soil particles to watercourses causes an increase in suspended solids.

COD and BOD$_5$: **Table 3** and **Figure 5** illustrate COD values for lake waters**.** COD values have been relatively high and far exceed WHO standards; With P = 0.00023. This confirms the presence of a large proportion of non-biodegradable organic matter. Except for the measures carried out in S7 and S8 or the value of the DCO is compliant with standards: Station S1P3 has presented the (580 mg · L-1) whereas the site S8P3 had the lowest value (74 mg · L-1). Compared to the results of the work of previous Manzala Lake, in Egypt, by Abd El-Kawy Zahran [25], the waters of Lake of Réghaia are characterized by significant levels in COD.

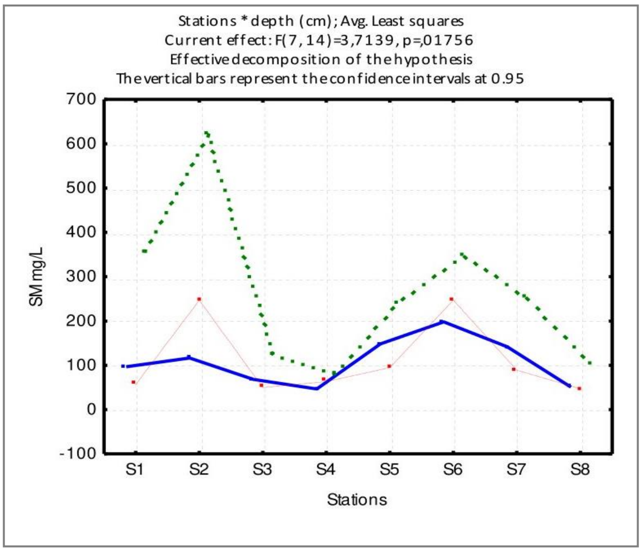

Figure 4. Spatial variation of MS in mg/l in Reghaia Lake.

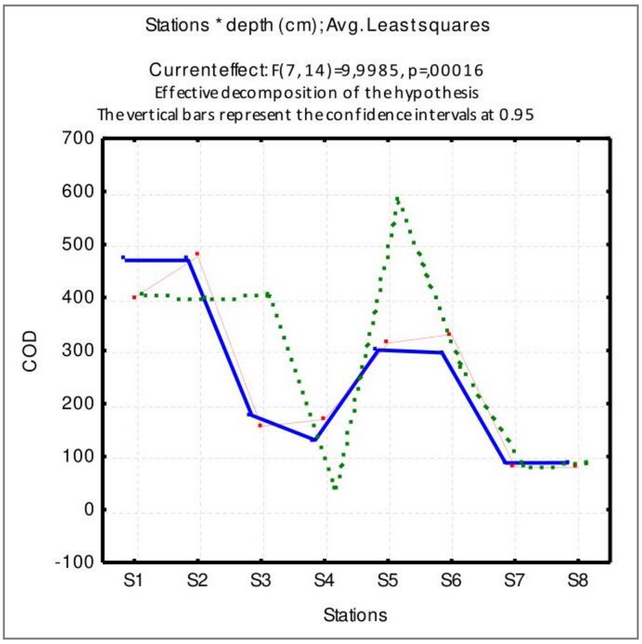

Figure 5. Spatial variation of COD in mg/l in Réghaia Lake.

The values of the biochemical oxygen demand are represented in **Table 3 and Figure 6**. The values of the BOD5 largely exceed the standards of WHO [24]; a gradient is emerging of the station (S1) with an average of 395mg/L until the station (S8) with an average of 41.35 mg/L. According to Nisbet and Verneaux [26], the values of the BOD5 > 6 mg/L reveal an abnormal situation of the water. It is valid for the results obtained on the same course of water the Rhumel, by Bentellis *et al.*, [27]. The report of biodegradability COD/BOD$_5$: these two parameters of pollution present a similar evolution with a report of COD/BOD5 which is 2.65 **(Figure 7)**. This confirms the presence of a large proportion of organic matter not biodegradable.

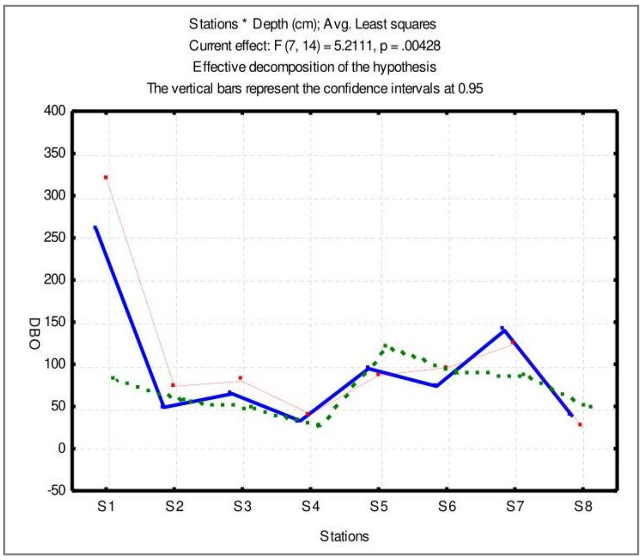

Figure 6. Spatial variation of BOD in mg/l in Reghaia Lake.

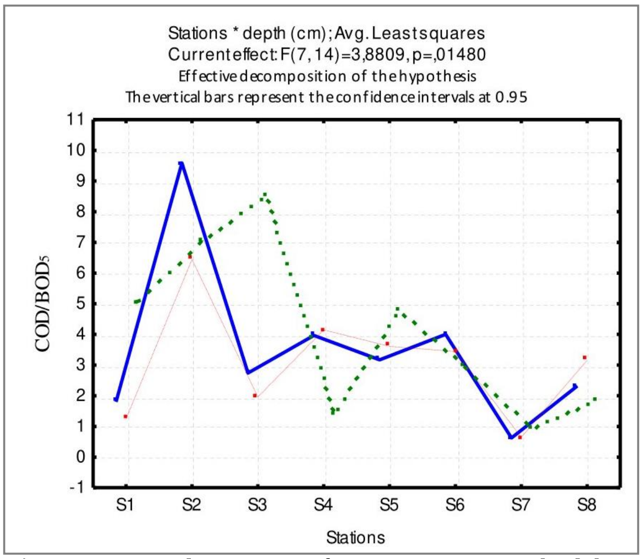

Figure 7. Spatial variation of COD / BOD5 In the lake of Reghaia

At the level of the waters of the different sampling stations, the mean values of the DCO far exceed those of the BOD5. This state of fact reflects the predominance of a pollution of various origins (industrial, agricultural, urban), excessive to these level there, except the Station St4. In such excessive pollution results in a critical situation which, according to El-Morhit [28], is reflected most often by a strong fish mortality following a suffocation of fish. Indeed, these relatively high levels of COD compared to those of BOD5 could certainly reflect the presence of a low biodegradable load dominated by a micro-pollution (heavy metals) masked possibly by the organic load. Thus, the results of this study could be related to the very important marked seasonal variations at these stations. Also, during rain events, run by the transport of soil particles to watercourses causes an increase in suspended solids. The variation curves of pH, Temperature (T°), electrical conductivity, COD, BOD5, PO_4^{3-}, represent the evolution of these parameters in space on profiles from upstream to downstream of the Reghaia lake during the period spanning the month of February 2016 until August 2016.

Variation of heavy metals: The levels of heavy metals in the lake are variable from one point to another. The **Figures (8 -15**) illustrate these variations as a function of space and depth. The iron varies between 0.4 and 10.1mg / L from the surface to the depth of the lake and between 5.74 to 1.37 from the inlet to the outlet (**Figure 8**), the Fe values far exceed the WHO standards [24] with P=0.013783.

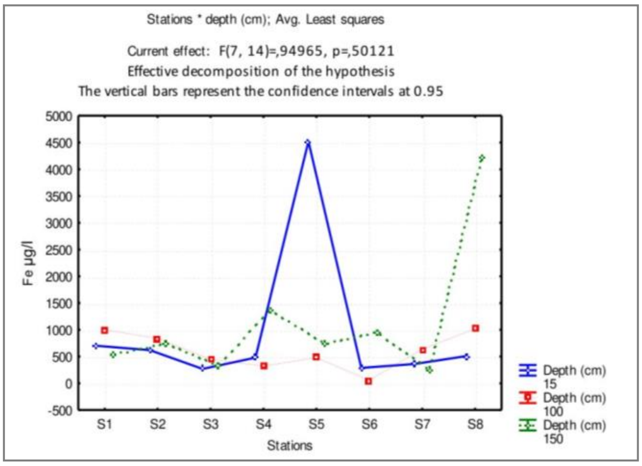

Figure 8. Spatial variation of Fe in µg/l in the Reghaia lake.

Zinc levels range from 0.01 to 0.2mg/L of the surface to the depth of the lake and for lake entry the content is 0.1 mg/L. While for the dam is the concentration of this element is the order 0.04 mg / L (**Figure 9**).

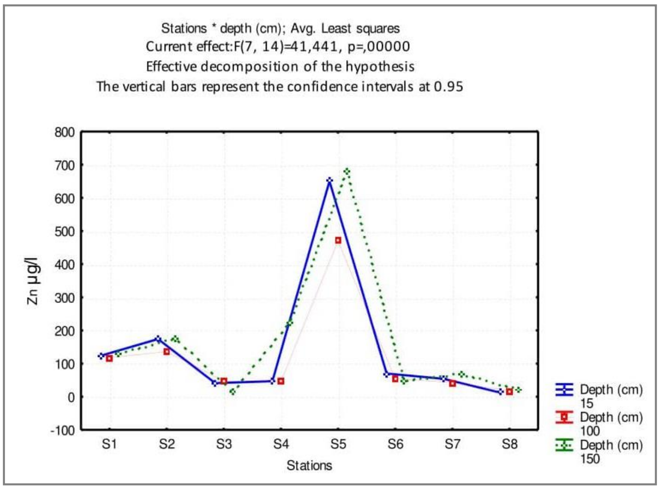

Figure 9. Spatial variation of Ni in µg / l in the Reghaia lake.

Copper varies between 0.09 mg/L and 1.37µg/L upstream to the dam of the lake and 10 µg / L to 0.05 mg /L the surface to the depth during the month of April (**Figure 10**). This corresponds to the maximum of primary productivity of the spring and can be connected to the fact that the copper between in the composition of various respiratory pigments (prothidic metal,chlorocruorin) Crustaceans constituting the zooplankton [29] .

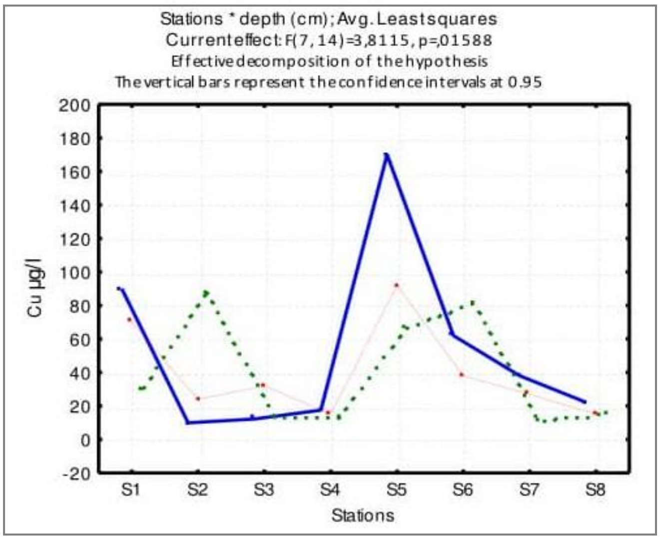

Figure 10. Spatial variation of Cu in µg /l in Reghaia lake.

Figure 11 shows that the value of Nickel ranged from 0.027 to 0.04mg / L from upstream to the lake dike and between 40 to 10 µg / L from surface to depth.

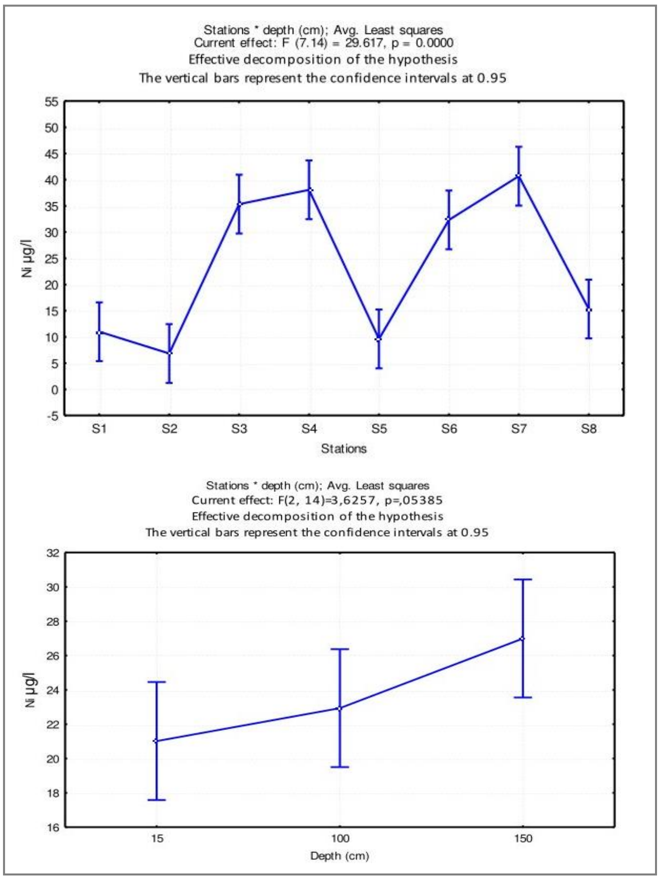

Figure 11. Spatial variation of Ni in µg/l in the Reghaia lake.

Cadmium: S1P3 Station presented the maximum value (0.02 mg · L-1) while the site S8P3 showed the lowest value (0.014 mg · L-1). The Cd values far exceed the standards of WHO [24] (P = 0.000092) (**Figure 12**).

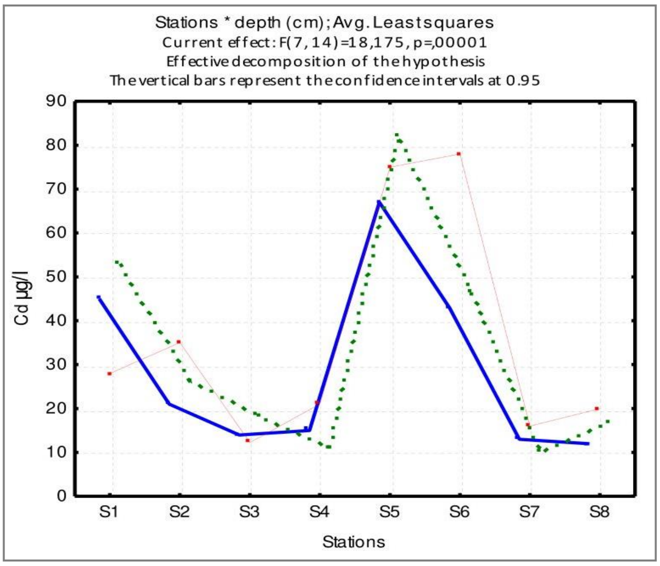

Figure 12. Spatial variation of Cd in µg / l in Reghaia lake.

The levels of lead are variable from one station to another (**Figure 13**), the maximum value is 0.059 mg/L recorded in station S8P3. The minimum value is stored in the S5P1 station (0.01mg / L). Pb values well exceed WHO standards [24] with P = 0.001771.

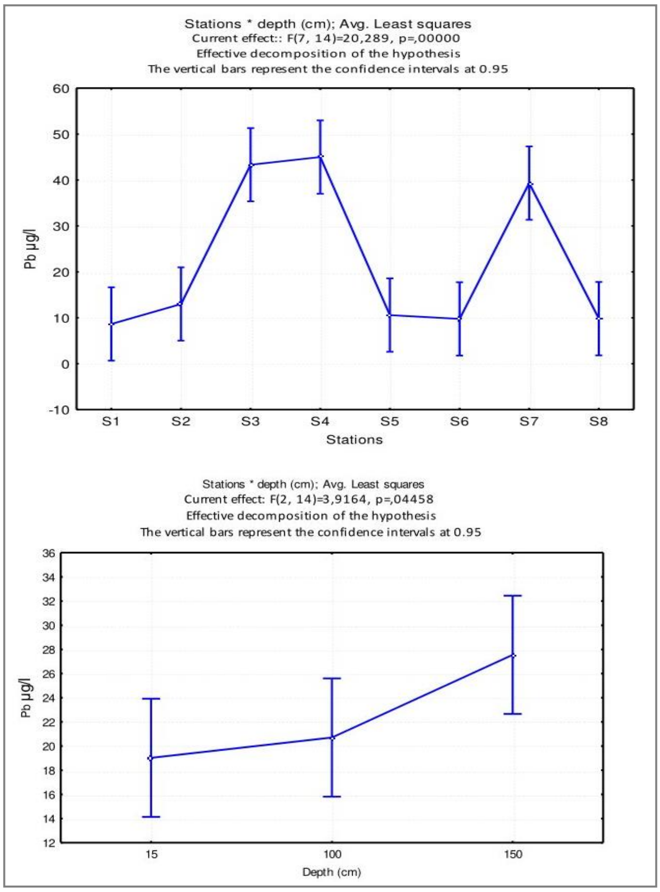

Figure 13. Spatial variation of Pb in µg / l in Lake Reghaia.

The concentrations of Cobalt and Ag vary in a similar way, relatively low (**Figures 14,15**), respectively of the order of 2.1 and 5 µg · L-1.The measured concentrations show the following classifications: Fe> Zn> Cu> and Ni>

Cd> Pb> Co> Ag. It is characterized by the minimum cobalt and silver concentrations and by a decrease in copper and lead contents.

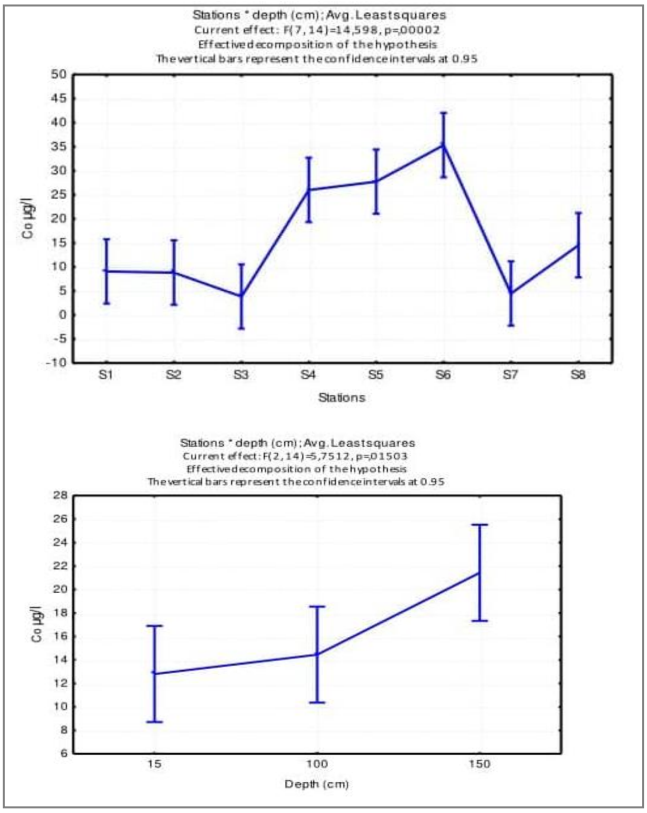

Figure 14 Spatial variation of Co in µg/l in the Reghaia lake.

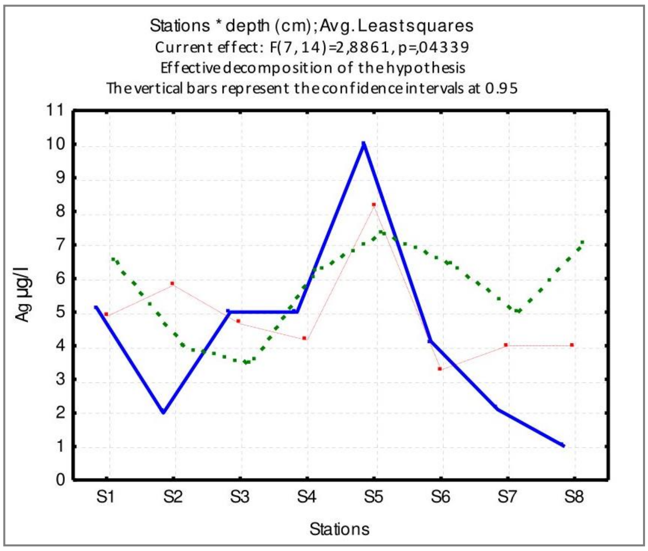

Figure 15 Spatial variation of Ag in µg/l in Reghaia lake.

During periods of intense primary productivity, the number of living organic particles suspended in water is greater, The phenomena of adsorption and biological concentration of the minor elements then become more intense, which tends to reduce their concentrations in the dissolved state [29]. These high concentrations are related to contamination by landfill leachates, which are rich in heavy metals [30]. The waters of Lake Reghaia remain victims of a major industrial and urban pollution hence the urgency of establishing a comprehensive strategy for the protection of these how large bodies for sustainable development. Prevention is the best way to fight against surface water pollution. Relevant and effective prevention must pass inevitably by reducing pollution at the source and the systematic evaluation of the current state of water and water bodies [31].

In general, toxic metals come from the combustion of coal, oil, household refuse and some particular industrial processes**.** They are mainly from waste incineration factories and car traffic [32]. In addition, the elements metal traces are also naturally present (geochemical background) Rahmoune *et al.,* [33]. Some metals are essential (such as zinc) because they are an integral part of at least one enzyme, and as the primary action of these essential metals is to act as a catalyst, only traces are necessary for a function optimal cell [34].

From **Table 4 and 5**, there is a significant positive correlation between Fe with Cu, r in the water of the lake (Ag =0.6); Fe, Cu (r =0.43) and correlates negatively with Co and Pb in the hydrosol as r = -0.57 for each. The copper showed a significant positive correlation with Cd, Zn and Ag in the water where (r = 0.64; 0.67; 0.57) and correlates negatively with Pb and Ag as r = -0.4 for each. The zinc correlated with Cd, Ag (r = 0.6 and 0.68) and with neither correlates negatively (r = -43). Cd positively correlated with Co, Ag in the water (r = 0.56) and correlates negatively with nor with r = -0,43, Pb showed a significant positive correlation with the Ni (r = 0.79) .

It is obvious that the heavy metals with a positive correlation have been regarded as having similar sources to those estimated by Dan *et al.*, [35]. According to **Table 6**, the values of ETM measured in the whole of the stations of the lake of Reghaia are significantly higher than those found in the lake of other countries such as Mexico, Egypt, and Nigeria (**Table 7**).

Table 7. Comparison of results obtained from physicochemical characteristics with other authors.

Parameter	Reghaia Lake[1]	Lake Dianchi[2]	Tropical Mexican Lake[3]
COD mg · L-1	216.71	18.6	34
BOD 5 mg ·L-1	80	17.7	/
DO mg · L-1	0.54	5	12.5
CE µS · cm-1	199.67	285	840
$PO4^{3-}$ mg · L-1	2.82	/	0.7
SM mg · L-1	250	/	/

[1] **present study; [2] Yunnan [19]; [3] Ref [20].**

Table 4. Descriptive statistics of eight metals (expressed as total metal) measured in the waters of ten sites in Reghaia Lake.

Stations	Fe mg/L	Cu mg/L	Zn mg/L	Cd mg/L	Pb µg/L	Co µg/L	Ag µg/L	Ni µg/L
S1P1	0.7	0.09	0.124	0.045	8.887	9.45	5.14	10
S1P2	1	0.07	0.118	0.028	8.368	8.23	4.87	12
S1P3	5.47	0.03	0.129	0.053	8.659	10.1	6.54	11
S2P1	0.62	0.01	0.174	0.021	11.06	8.12	2	10
S2P2	0.84	0.024	0.136	0.035	15.06	9.21	5.8	0.5
S2P3	7.45	0.088	0.178	0.026	12.86	10.14	4	10
S3P1	0.27	0.0122	0.041	0.014	38	4,5	5	27
S3P2	0.45	0.032	0.048	0.0123	33	2	4.65	39
S3P3	0.31	0.128	0.14	0.018	59	3.01	3.5	40
S4P1	0.48	0.0175	0.047	0.015	32	28	5	31
S4P2	0.32	0.0153	0.046	0.021	41	41	4.16	34
S4P3	1.37	0.0127	0.22	0.011	62	32	6.17	49.21
S5P1	4.52	0.17	0.65	0.067	9.1	16	10	10.14
S5P2	0.48	0.092	0.47	0.075	10.02	28	8.14	8.99
S5P3	0.75	0.067	0.68	0.082	12.62	39.25	7.35	9.72
S6P1	2.87	0.062	0.07	0.043	8.15	23	4.13	31
S6P2	0.58	0.038	0.054	0.078	10.08	35	3.28	34
S6P3	0.97	0.081	0.51	0.0462	11.03	48	6.47	32
S7P1	0.36	0.038	0.054	0.013	36	4.8	2.1	35
S7P2	0.64	0.027	0.043	0.016	38	2.14	4	42
S7P3	0.23	0.012	0.067	0.01	44	2	5.02	45
S8P1	0.51	0.0221	0.012	0.012	9.02	12.54	1	14
S8P2	1.02	0.0151	0.018	0.02	10.14	13	4	13
S8P3	4.21	0.0156	0.021	0.017	10.25	18	7	19
Average	903.62	43.83	144.37	32.43	22.43	16.23	4.97	23.65
Minimum	58	10	12	10	8.15	2	1	0.5
Maximum	4520	170	680	82	62	48	10	49

Table 5. Coefficients of heavy metals correlation of water from Lake Reghaia.

Variables	Correlations							
	Fe µg	**Cu µg**	**Zn µg**	**Cd µg**	**Pb µg**	**Co µg**	**Ag µg**	**Ni µg**
Fe µg	1.00	0.43	0.38	0.11	-0.24	0.08	0.60	-0.26
Cu µg	0.43*	1.00	0.67*	0.64*	-0. 49	0.23	0.57	-0.41
Zn µg	0.38	0. 67*	1.00	0. 69*	-0.26	0.34	0. 68*	-0.43
Cd µg	0.11	0.64	0.69	1.00	-0.57*	0.56	0.54	-0.43
Pb µg	-0.24	-0.49	-0.26	-0.57	1.00	-0.21	-0.17	0.79*
Co µg	0.08	0.23	0.34	0.56*	-0.21	1.00	0.38	0.05
Ag µg	0.60*	0.57	0. 68*	0.54*	-0.17	0.38	1.00	-0.24
Ni µg	-0.62	-0.41	-0.43	-0.43*	0. 79*	0.05	-0.24	1.00

* Significant correlations at $p < 0.05$. N = 24 (Observations to VM ignored).

Table 6. Comparison of the results of MTE with other authors.

Parameter	Reghaia Lake present study	Manzala Lake, Egypt [25]	Tropical Mexican Lake [20]	Households in Southwest Nigeria [36]
Fe µg	903.62	342.98	1400	30
Cu µg	43.83	17.50	-	-
Zn µg	144.37	29.08	-	10
Pb µg	22.43	21.39	400	50
Co µg	16.23	12.27	-	-
Cd µg	32.43	1.73	-	12
Ag µg	4.97	-	-	20
Ni µg	23.65	-	200	7

Conclusion

The waters of the lake of Reghaia are affected by different types of pollution: Industrial, urban and agricultural fact that they constitute the first receiver of the various releases. This contamination is marked by high levels of PO_4^{3-}, NO_2, COD, BOD and SM…etc. The physicochemical variables analyzed the waters of Lake Reghaia are located in the international values (WHO). The phosphates exceed the standards of the WHO in the present study. Urban pollution is evidenced by the presence of PO_4^{3-}, and NO_2 of high concentrations. Industrial pollution is reflected by the presence of Ni, Cd, and Pb. The spatial distribution of metals in different sampling stations shows that the stations St1 and St5 St6 have the highest content of Iron, Zinc, and Nickel. The waters of Lake Reghaia be of poor quality and ecosystem degradation is increasingly enhanced, require treatment.

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