ENVIRONMENTAL STATUS OF THE BAY OF JOUNIEH THROUGH THE EVALUATION OF ITS MARINE SEDIMENT'S CHARACTERISTICS

Milad Fakhri, Abir Ghanem, Myriam Ghsoub and Afif Ghaith
National Centre for Marine Sciences-CNRSL

(Received March 2018 – Accepted September 2018)

ABSTRACT

Fakhri, M. Ghanem, A. Ghsoub, M. and Ghaith, A. 2018. Environmental status of the Bay of Jounieh through the evaluation of its marine sediments' characteristics. Lebanese Science Journal. 19(3): 373-388.

Increasing anthropogenic pressure on one of the most frequented touristic coastal region of Lebanon, Bay of Jounieh, located to the North of Beirut urges the assessment of its coastal marine environmental state. Therefore, the geochemical, physical, chemical and biochemical characteristics of its sediments are analyzed and evaluated. The samples are collected from 3 three transects (North, Middle & South) at 3 consecutive depths 15, 30 and 60 m using the platform of the Lebanese scientific vessel "CANA-CNRS". The sediments of shallower sampling points, 15 and 30 m, are mainly composed of fine sand and are poor in most of the studied parameters except chlorophyll-a. While those of 60 m are exclusively represented by the fine fraction and contain maximum concentrations of organic matter (2.97%), calcium carbonates(47.7 %), phosphates (264 µg/g) and pheopigments (7.03 µg/g). The labile fraction through the 3 transects is represented by low concentrations of carbohydrates (0.011 - 0.06 mg/g), low concentrations of proteins (0.009 - 0.051 mg/g) and high levels of lipids (0.324 - 1.036 mg/g). The results show that the deep points (60 m) of Jounieh Bay are the most affected by the anthropogenic pressure combined with hydrodynamic factors and geomorphological issues. The environmental condition of Jounieh's Bay appears to be tolerant to the impact of multiform of contaminants to which it is been exposed since longtime and it is still able to show a meso-oligotrophic system with acceptable nutritive values for the proliferation of benthic organisms. This study is expected to provide a valuable tool for monitoring and research programs in other marine areas of the Lebanese coast.

http://dx.doi.org/10.22453/LSJ-019.3.373388

lsj.cnrs.edu.lb/vol-19-no-3-2018/

Keywords: Lebanon, Jounieh Bay, sediments, depths, pollution, biogeochemical parameters.

INTRODUCTION

The continental margin of the central Levant, offshore northern Palestine and Lebanon is characterized by a sharp continental-oceanic crustal transition, exhibited on the bathymetry as a steep continental slope. The western Lebanese continental margin, in the eastern Mediterranean Sea, extends from the Lebanese coastal belt up to 10 km west.

Jounieh bay area is poorly explored, its offshore coastal strip is characterized by a very narrow continental shelf, crossed by deep canyon that, from a short distance from the coast, goes down to depth of one thousand meters. Offshore Jounieh bay, high resolution bathymetric data with full multi-beam coverage have revealed a dense network of submarine canyons within the depth range from 80 to 1400m, across a wide range of morphologies settings. The Jounieh Bay canyon (Eastern Mediterranean Sea) where sediments are transported across the slope, is aligned with a prominent land valley near the center of Jounieh Bay and has a northern tributary which is roughly in line with an important fault and shear zone near Ras-el- Maameltein (Goedick & Sagebiel, 1973).

Its seabed topography is the continuation of inland geomorphology with its almost absent coastal plain on which agglomerations have developed, and steep hills belt exceeding in elevation 500 meters, in less than 1 km from the coast.

The coastline of Jounieh Bay is stretched in a semicircle, surrounded by several cities: Kaslik, Jounieh, Maameltein and Tabarja and is considered as one of the most frequented touristic coastal region of Lebanon. The northern part of the Bay contains the "Casino of Lebanon", a famous place that helps in the prosperity of that area.

Bay of Jounieh is facing the threats of uncontrolled urbanization with illegal construction expansion along the sea side altering the natural landscape and promoting the release of high inputs of untreated sewage water. The Bay is under the influence under of a wide range of anthropogenic impacts due to its port of pleasance and the numerous marinas projects including fishing, diving activities, leisure boats, restaurants, night clubs. The Bay of Jounieh might be also affected by the discharges of the power plants lying at its northern side (Hamdan, 1998).

The evaluation of sediment is considered an important tool for pollution monitoring more than the water evaluation. Marine sediment is an investigator of the environment history with all its human activities that affect the sediment characteristic, status and composition. It is a final destination and an efficient natural trap for natural and anthropogenic contaminants. It is also a natural regulator of the processes that occur inside the sea floor. Sediment can store large amounts of organic matter and affect the oxygen content of bottom water (Burone *et al*., 2003) It also constitutes a source of nutrients for the water column above them leading to benthic-pelagic coupling and influencing primary productivity (Jørgensen & Richardson, 1996).

This investigation aims to evaluate the state of environment of Jounieh Bay, to reveal the impact of anthropogenic activities, to get better understanding of the sources and distribution of multiple contaminants, and to have a reference for future investigation by studying the variation of geochemical, chemical and biochemical characteristics of marine sediment.

MATERIAL AND METHODS

With the help of the Lebanese scientific vessel CANA-CNRS, the samples of sediment are collected from the Bay of Jounieh at 3 designated depths (15, 30 and 60 m) along 3 horizontal transects located to the north (NJ), to the middle (MJ) and to the south (SJ) of the bay (Table 1, Figure 1) during spring season of 2013. A stainless steel Van Veen grab is used and the upper 5 cm of surface sediment are kept for analysis. All samples are freeze-dried for further analysis.

The grain size composition is determined by sieving the sediments on series of variable mesh size sieves (ranging between 2000 and 63 µm) on a Retsch AS200 siever. The organic matter is determined using the simple titration method approved by the Expertise Centre in Environmental Analysis of Québec (MA., 2010). Chlorophyll-*a* and pheopigments are extracted by acetone (90%) and calculated by spectrophotometry according to Lorenzen (1967) method modified by Magni *et al.* (2000). Calcium carbonate is measured according to UNEP (1995) manual by the loss of weight after addition of hydrochloric acid. The analysis of phosphate in sediment is processed by the adoption of the semi-automated method of Aspila *et al.* (1976). The 3 major biochemical components of the labile fraction are analyzed according to the method of Lowry *et al*. (1951) for proteins, that of Dubois *et al.* (1956) for total carbohydrates and the method of Marsh & Weinstein (1966) for lipids.

The statistical analysis is performed with the “R Project” for statistical computing. Two-way ANOVA without repetition is adopted to highlight the significant differences of mean values of variables between the depth and stations. Matrix of correlation is performed to estimate the strength of correlation between the different parameters and Principal Component Analysis “PCA” is applied to identify the group of stations that are supposed to have similar properties relying on the measured variables.

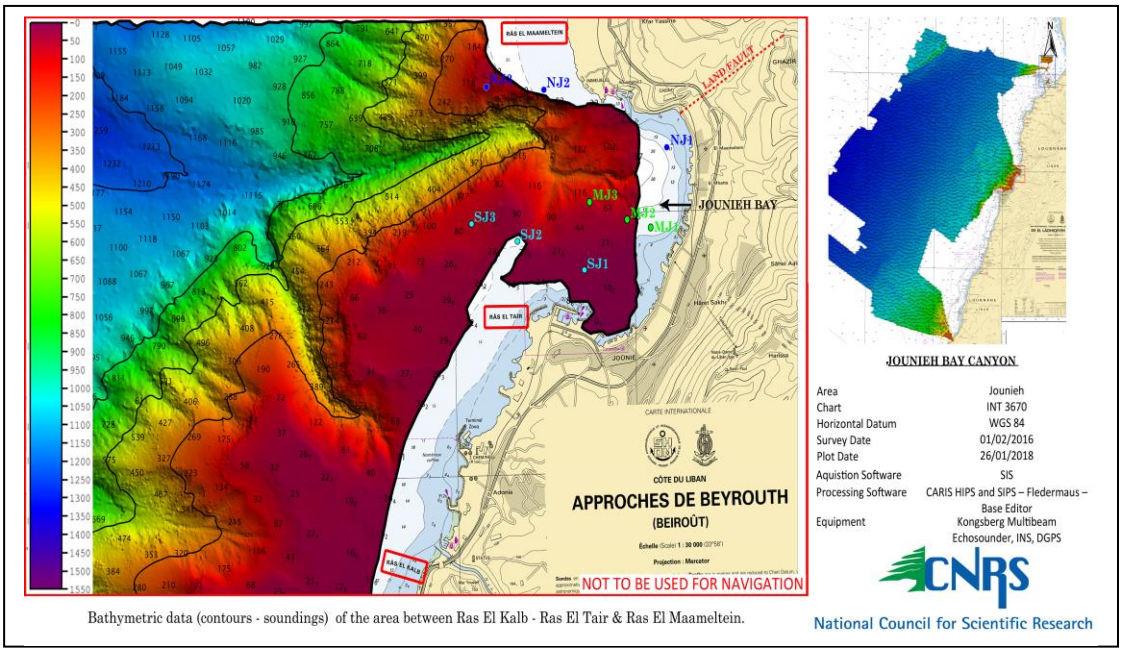

Figure 1. The bathymetry of Jounieh Bay including the sampling sites at the 3 transects.

Table 1. Coordinates, depth and redox status of the sampling points in the Bay of Jounieh.

Station	Latitude N	Longitude E	Depth (m)	Sediment Eh(mV)
NJ1	$34^0$00.501’	$35^0$38.399’	15m	103
NJ2	$34^0$00.976’	$35^0$37.050’	30m	31
NJ3	$34^0$01.017’	$35^0$36.407’	60m	-100
MJ1	$33^0$59.895’	$35^0$38.199’	15m	80
MJ2	$33^0$59.958’	$35^0$37.946’	30m	-188
MJ3	$34^0$00.105’	$35^0$37.531’	60m	-126
SJ1	$33^0$59.576’	$35^0$37.456’	15m	-72
SJ2	$33^0$59.815’	$35^0$36.719’	30m	-65
SJ3	$33^0$59.955’	$35^0$36.212’	60m	-127

RESULTS

Grain size composition

At the northern transect the sediments of NJ1 sampling point (15 m depth) were mainly made up of mid-size and fine-sand fractions (42% and 46% respectively). At NJ2 (30 m depth) the sediments were dominated by fine sand (75.3%) with only 8.9% of fine fraction. The deepest sampling point, NJ3, was exclusively composed of fine fraction (100%).

Through the middle transect, the sediment grain size composition at MJ1 was distributed between fine sand (55.9%), mid-size sand (23%) and coarse sand (20.7%). Similar to the northern section, MJ2 was dominated by fine sand (88.3%) with only 1.2% of fine fraction and MJ3 was totally composed of fine fraction. In the southern transect, the two shallower sampling points SJ1 and SJ2 were mainly composed of fine sand, 94.7% and 83.3% respectively, while fine fraction totally dominated SJ3 (Figure 2).

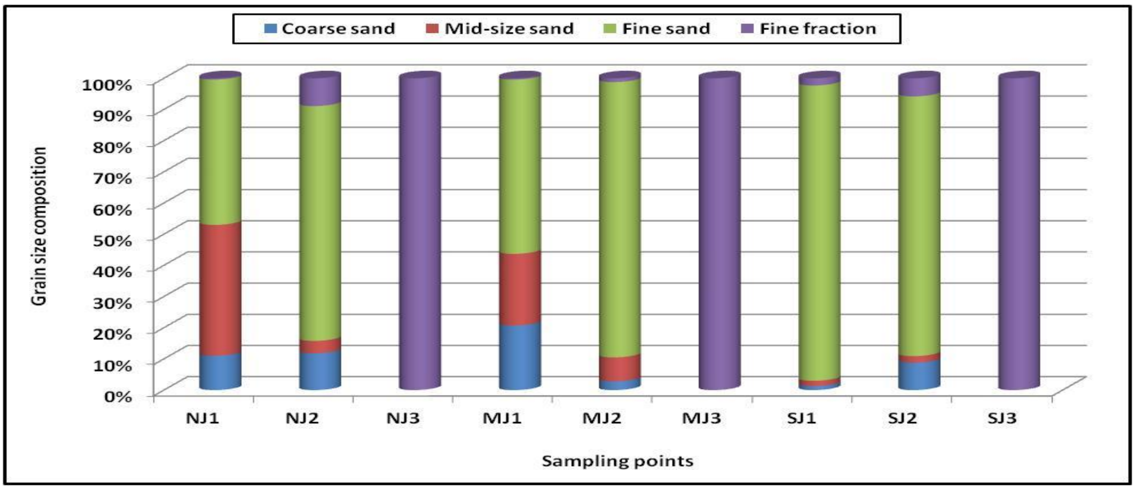

Figure 2. Grain size composition of sediments of Jounieh Bay.

Organic Matter

The distribution of organic matter in sediment followed the same trend along the 3 transacts and its percentage increased with depth, the lowest value (0.22 ± 0.05) was recorded at MJ1 and the highest 2.97 ± 0.12% at SJ3 (Figure 3).

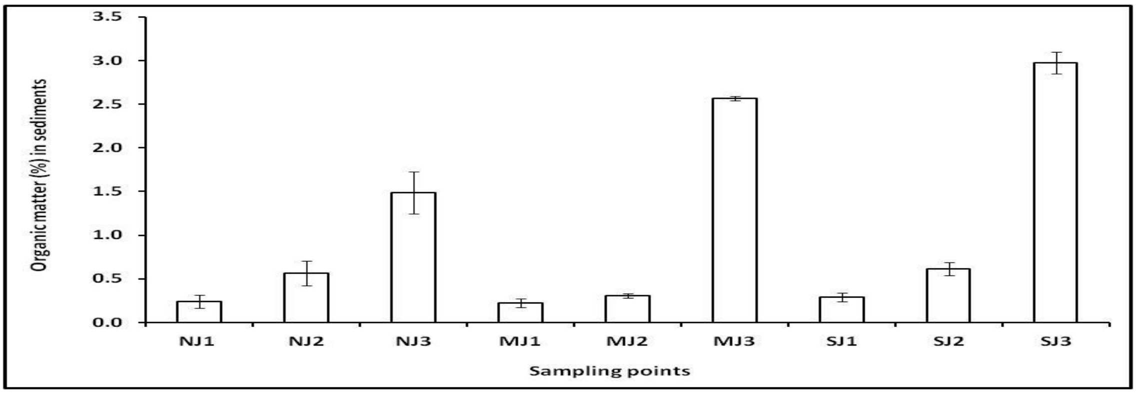

Figure 3. The percentage of organic matter (± SD) in the sediments of Jounieh Bay.

Chlorophyll-*a*, pheopigments & chl-*a* /pheo Ratio

At the northern transect, the concentration of chlorophyll-a decreased from 1.17 µg/g in the sediment of NJ1 to 0.57 µg/g at NJ3. The concentration at the southern transect decreased also with depth from 2.44 µg/g at SJ1 to 0.7 µg/g at SJ3. At the middle transect the concentration increased from 1.44 at MJ1 to 2 µg/g at MJ2 then decreased again at MJ3 (1.34 µg/g).

Through the 3 transects the concentrations of pheopigments showed a constant increase with depth. The lowest value (0.33 µg/g) was measured at NJ1 and the highest (7 µg/g) at MJ3. The chl-*a*/pheo ratio decreased with depth through all transects. At 15 m depth it was >1 with maximum value of 11 at MJ1 while at 30 and 60 m the ratio was < 1 (Figure 4).

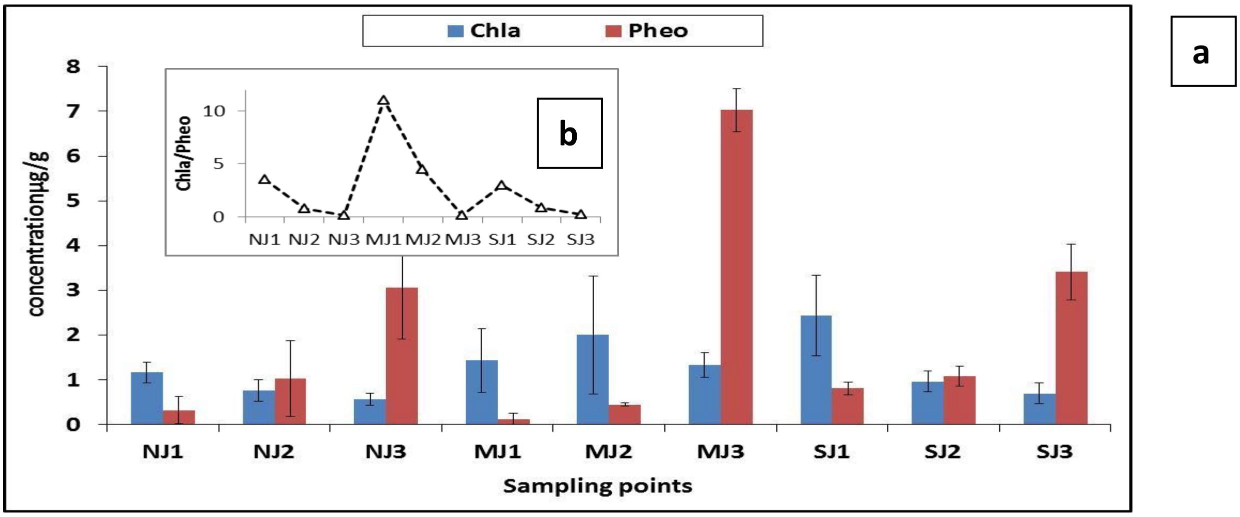

Figure 4. (a)The concentrations of Chlorophyll-*a* and pheopigments (± SD) and (b)The Chla/Pheo ratio in the sediments of Jounieh Bay.

Calcium carbonate

The percentage of calcium carbonate increased with depth in all transects, the lowest percentage of calcium carbonate 12.5 ± 0.2% was recorded in the sediment of MJ2 and the highest value of 48 ± 8% at NJ3. The northern transect seems to contain more CaCO3 than the 2 others (Figure 5).

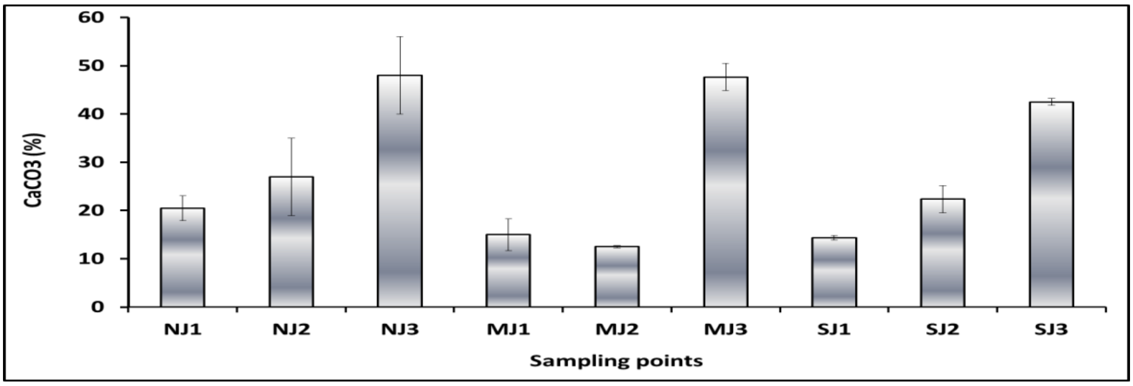

Figure 5. The percentage of calcium carbonate (± SD) in the sediments of Jounieh Bay.

Total phosphates

The concentrations of total phosphate followed the same trend through the 3 studied transect by increasing with depth. They ranged between a minimum value of 39 ± 1 µg/g at NJ1 to a maximum value of 264 ± 28 µg/g at MJ3 (Figure 6).

The inorganic fraction seems to dominate the total phosphate in the sediment of Jounieh bay, except at MJ3 with a dominance of organic phosphate of 52% (figure 7).

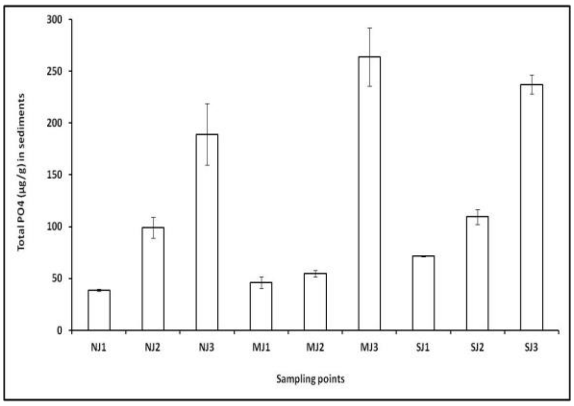

Figure 6. Total phosphate (± SD) in the sediments of Jounieh Bay.

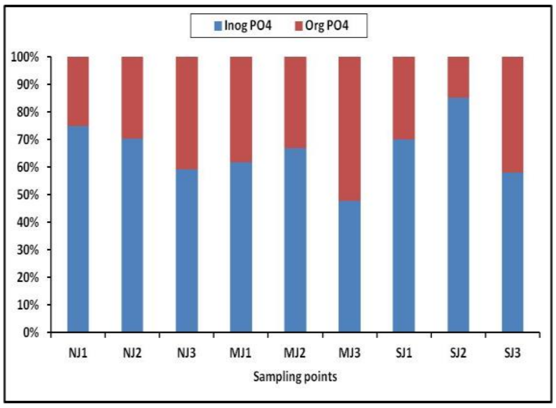

Figure 7. Distribution of the percentages of inorganic and organic phopshate in the sediments of Jounieh Bay.

Labile fraction: Proteins, Carbohydrates & Lipids

The concentrations of proteins were low in the sediments of the whole Bay of Jounieh. The comparison among transects showed that the northern one contained the least of proteins concentrations (0.009 to 0.025 mg/g) and the southern transect contained the most (0.016 to 0.053 mg/g) (Figure 8a).

Like for the proteins, the sediments of Jounieh Bay were found to be poor in carbohydrates.

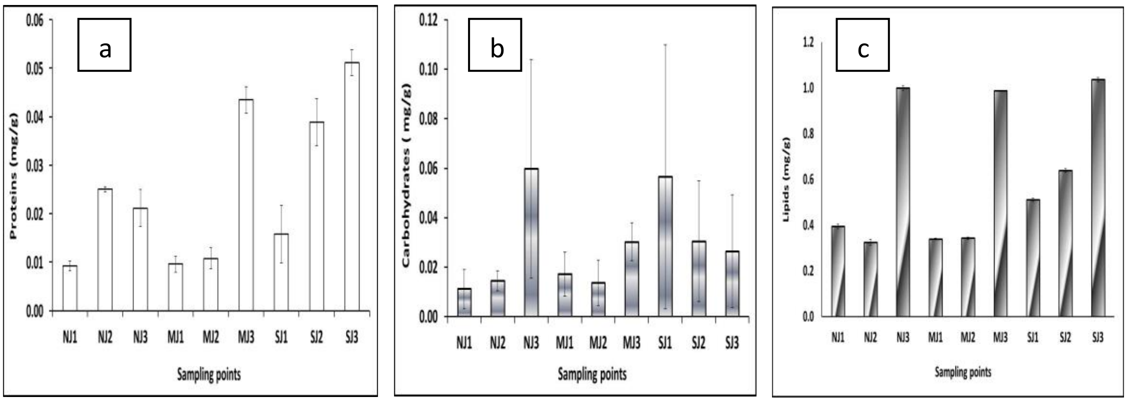

Figure 8. The concentrations (± SD) of: (a) proteins, (b) carbohydrates, (c) lipid in the sediments of Jounieh Bay.

Through the northern transect, the concentrations of carbohydrates increased from 0.011 mg/g at NJ1 to a maximum of 0.06 mg/g at NJ3. On the contrary, through the southern transect, carbohydrates concentrations followed a descending trend while proceeding offshore (0.057 mg/g at SJ1 to 0.026 mg/g at SJ3). The middle transect contained the least of carbohydrates (Figure 8b). The labile fraction was well represented by lipids in the sediment of Jounieh Bay. The 3 transects showed almost similar distribution of lipids with depth with a small advantage for the southern transect, which showed the highest concentrations (from 0.510 mg/g at SJ1 to 1.036 mg/g at SJ3 (Figure 8c).

Proteins/Carbohydrates (PRT/CHO) & Lipids/Carbohydrates (LPD/CHO) Ratios

Table 2. Proteins/Carbohydrates & Lipids/Carbohydrates ratios in the sediments of Jounieh Bay.

Stations	PRT/CHO	LPD/CHO
NJ1	0.82	35.25
NJ2	1.72	22.36
NJ3	0.35	16.71
MJ1	0.56	19.69
MJ2	0.79	24.95
MJ3	1.44	32.70
SJ1	0.28	9.02
SJ2	1.27	20.97
SJ3	1.94	39.20

The proteins/carbohydrates ratio varied between 0.28 and 1.94, while the ratio lipids/carbohydrates ratio fluctuated between 9.02 and 39.20 (Table 2).

Application of principal component analysis

The principle component analysis (PCA) revealed the presence of two main components: the first component (Dim1) explains 69% of the total variance while the second component (Dim2) represents 14%. The principal plan of the stations (Individuals' graph) represents the gathering of sampling points with similar properties according to the first two principal components (Figure 9). The second plot represents the variables factor map (circle of correlation) and shows the distribution of all the variables according to the two components (Figure 10).

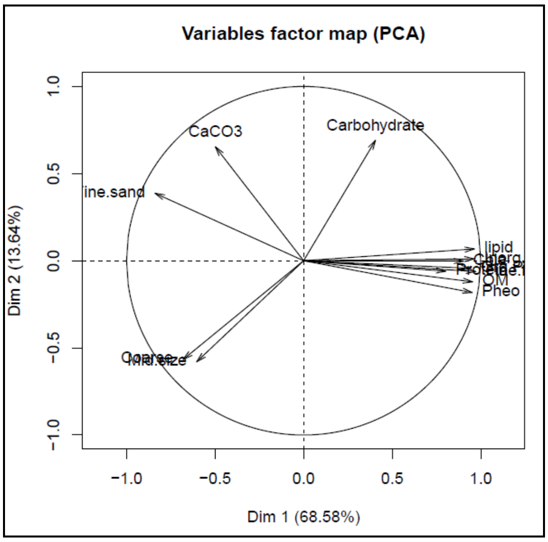

Figure 9. The principal plan of the stations (Individuals) in Jounieh Bay.

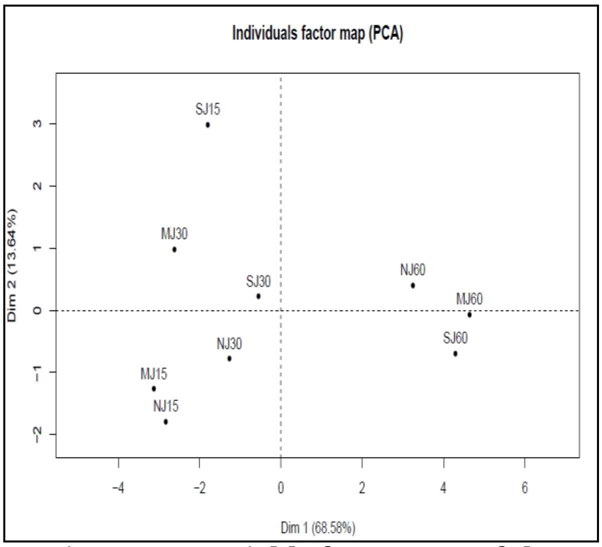

Figure 10. Variable factor map of the parameters in the marine sediments of Jounieh Bay.

DISCUSSION

While moving deeper the size of particles decreases and the percentage of fine fraction increases to be 100% at 60 m. The hydrodynamic factors seem to play a major role in the distribution and deposition of particles, carrying the lighter particles away from the coast. The accumulation of fine particles is accompanied with negative low redox potentials (Table1). This reduced state of sediments shows the presence of anoxic environment, translated by the black color and hydrogen sulfide smell (Fakhri *et al.*, 2008).

The values of organic matter detected in the bay were within the normal range usually measured in coastal marine areas. The increase of organic matter gradient with depth might be related to the dominance of the fine sedimentary fractions at the deepest sites and its capacity in creating more anoxic environment by preventing the oxidation of organic matter leading to its preservation (Lazar *et al*., 2012). A strong correlation appeared to exist between the concentrations of organic matter and the percentage of fine fraction ($r=0.94$, $p<0.001$, $k=16$).

The effects of hydrodynamic factors combined to the narrowness of the continental shelf inside the bay might be responsible for the redistribution of the suspended particles deriving from the sources of pollution extending along Jounieh coast and the transfer of fine particles containing organic matter from shallower into deeper depth levels (MoE/UNDP, 2011). It is known that the wave action is a principal hydrodynamic phenomenon responsible for the bottom sedimentary processes (Furtado & Mahiques, 1989) and turbidity currents redistribute the trapped organic matter into deeper levels (Buscail *et al*., 1995).

The low concentrations of chlorophyll-*a* in the sediments of the Bay of Jounieh might be related to their degradation into pheopigments. The predominance of pheopigments mainly in deep sediments might be attributed to strong anthropogenic stresses that impact the photosynthetic potential of the primary producers (Renjith *et al*., 2013). When referring to chlorophyll-a/pheopigments ratio as indicator used for assessing the quality and freshness of organic matter (Misic & Harriague, 2013), it shows that highest ratio at MJ1 indicates that this site is less perturbated and contains fresh organic material while the lowest ratios at NJ3, MJ3 and SJ3 showed the presence of stressed cells and accumulated old organic matter proved by the strong correlation that was established between fine fraction and pheopigments ($r=0.85$, $p<0.001$, $k=16$)and organic matter and pheopigments ($r=0.86$, $p<0.001$, $k=16$).

Calcium carbonate and phosphate are found to accumulate in the sediment of deepest sampling points. The fine fraction that is dominating the line of 60 m is strongly correlated with calcium carbonate ($r=0.94$, $p<0.001$, $k=16$) and total phosphate ($r=0.90$, $p<0.001$, $k=16$). The increase in calcium carbonates concentrations may be attributed to the decomposition and the sinking of the shells and some aquatic organism such as Coccolithophores, foraminifers, gastropods and bivalves (Karageorgis *et al*., 2004) while the accumulation of total phosphate may be related to the discharge of domestic, agricultural and industrial waste water. But it is necessary to mention high concentrations of phosphate don't lead always to eutrophication (Correll, 1998) but they, till certain limits, may influence positively the living organisms by providing a fertilizing agent for their proliferation (Fakhri *et al.*, 2013).

The labile fraction represented by proteins, carbohydrates and lipids, is used to determine the nutrition values of the sediments of the Bay of Jounieh.

The low concentrations of proteins showed that the bay might be considered a productive marine area. Low concentrations of proteins like at 15 m and 30 m depth may indicate either their rapid utilization by benthic organisms or the low input of organic matter (Sane *et al.*, 2012). As the 60 m depth contained additional proteins, this could be related to recently deposit organic matter or to partially degraded organic matter derived from both primary production and anthropogenic source (Garcia-Rodriguez *et al*., 2011).

The low concentrations of total carbohydrates may indicate the high nutritive aspect of organic matter in the Bay of Jounieh and their freshness since carbohydrates show aged and refractory nature (Renjith *et al.*, 2013).

In comparison with proteins and carbohydrates, the high concentrations of lipid might be linked to the presence of leisure ports, boats, human wastes (Fichez, 1991a) or due to the association with hydrophobic organic micropollutants (Silva, 2011). Actually, the lipids bulk may also include non-autochthonous compounds, such as hydrocarbons, because the methods used to extract lipids from sediments may also recover significant quantities of organic contaminants (Galois *et al.*, 2000) thus, overestimating the real trophic quality. This fraction may be responsible for the significant increase in the lipids concentrations (Misic *et al.*, 2013).

The high concentrations of lipids may also show the presence of an energetic source in nutrition for heterotrophic metabolism in sediments (Fichez, 1991b). The decomposition of this highest energetic compound is delayed in an oxygen–restrictive condition (Carreira *et al.*, 2002; Pinturier-Geiss *et al*., 2002) as in almost all sampling points except NJ1, NJ2 and MJ1. This may be an additive factor for the high concentrations of lipids leading to its preservation under highly anoxic conditions. Moreover, there was an important effect of the depth on lipid, since the p-values of lipid 0.042 was smaller than the significance level ($\alpha = 0.05$) in a two-way ANOVA without repetition analysis, while all the other variables showed no significant difference with depth. In addition, there were no correlation recorded in the matrix of correlation between biochemical labile compounds and chlorophyll-*a* and this may indicate a higher contribution of allochthonous materials of anthropogenic origin and a lower contribution of phytobenthic population (Cotano & Villate, 2006).

High PRT/CHO ratios might be related to the arrival of anthropogenic wastes. They show the contribution of fresh organic matter since protein is usually mineralized faster than carbohydrates by bacteria, for that only fresh compounds show high index of PRT/CHO (Cotano & Villate, 2006) especially when the PRT/CHO ratio ranged from 0.2 to 1.94 indicating that the sediments were characterized by fresh organic matter (Kumar *et al.*, 2013). The low protein/carbohydrate ratios that are below 1 suggest the presence of aged organic matter. This ratio ranges from lower than 0.1 in oligotrophic Eastern Mediterranean Sea sediments (Danovaro *et al*., 1993) to higher than 10 in coastal Antarctic sediments (Pusceddu *et al*., 1997). Hence the values in Jounieh Bay are higher than the case of an oligotrophic state. Values of the proteins/carbohydrates ratio > 1 are associated with recently produced organic matter from different non-source points.

The LPD/CHO ratio is a useful index of energetic (food) quality of the organic matter. High LPD/CHO ratio indicates high quality of labile organic matter to support benthic fauna. Higher PRT/CHO and LPD/CHO ratios provided evidence of high nutritional value as well as the freshness of labile organic matter (Renjith *et al*., 2013).

Dell´Anno *et al*. (2002) defined meso-oligotrophy for protein concentrations <1.5 mg/g and carbohydrate concentrations < 5 mg/g. In Jounieh Bay, the concentrations of protein and carbohydrate ranged from 0.009 mg/g to 0.051 mg/g and from 0.011 mg/g to 0.06 mg/g, respectively. According to this classification, the trophic condition of Jounieh Bay is considered meso-oligotrophic. In spite of the continuous exposure of different sources of contaminants, nutrient loads from sewage outfall, industrial installations, leachates from fertilizers and leisure boats, the Bay of Jounieh is still able to adapt and provide nutritive values that are acceptable for primary production and benthic organisms within it.

The circle of correlation shows that the first principal component, which contributes with 69% of the total variance, gives significant loadings on fine fraction, organic matter, chlorophyll-*a*, pheopigments, inorganic phosphate, organic phosphate, proteins, lipids and depth. All the latter parameters are clustered on the positive side of this component, while coarse, mid-size and fine sand are distributed around its negative side. Hence the first principal component shows that the texture and anthropogenic perturbations allow the accumulation of all these parameters together. The position on the individuals factor map of the first group of sites (NJ3, MJ3 and SJ3) that have the highest concentrations for almost all parameters, confirms that the 60 m depth (rich with fine fraction in all transects) is mostly affected by the anthropogenic activity. The shallower points, at 15 and 30 m, are less contaminated and are found on the negative side of the first component. The sampling points at 30 m in the northern, middle and southern transact (NJ2, MJ2 and SJ2) constitute a group with probably similar properties. For the shallow depth, 15 m, is split into 2 groups, one contains NJ1 and MJ1 and located on the negative side of the second component and another contains SJ15 alone located on the positive side of it. This SJ1 sampling point, which contains the second highest concentrations of carbohydrates in the whole bay, seems not to be affected by the potential sources of runoff, but varied according to the sediments mineralogy since it is affected by calcium carbonate (Youssef *et al.*, 2014) as presented in the circle of correlation. Carbohydrates can serve in the composition of the component storage in marine and terrestrial organisms as well as in the transport of organic matter from the surface to greater depths. According to Bohm (1973), polysaccharides are accompanied by carbonate skeleton sediments.

CONCLUSION

Sediment is a memory recorder to all interactions that occur in aquatic environment. In this study, the evaluation of the geochemical, physical, and chemical and biochemical characteristics of sediments from 3 different depths defined the trophic level of Jounieh Bay by being a meso-oligotrophic system, a moderate environment helpful for benthic organisms. The deepest sampling points at 60 m were found to be more contaminated than the shallower ones at 15 and 30 m in all the studied transects and they behaved as a sink for the fine fraction on which organic and mineral compounds are usually adsorbed.

The labile fraction of organic matter was exclusively dominated by total lipids and the low concentrations of organic matter, chlorophyll-*a*, pheopigments, total phosphate and the highest percentages of calcium carbonate in the northern transect reveal that this transect is the least stressed part of the Bay where shell animals may be able to grow. The middle and the southern transects are considered perturbed areas, more affected by terrestrial sources of contamination with particularly high values of lipids.

More samples are to be collected in order to follow-up the concentrations of all studied parameters because the case has tendency to develop into eutrophic if no treatments are implemented. As well as it crucial to determine the levels of some toxic pollutants in the sediment matrix of the whole Bay such as trace metal elements, polycyclic aromatic hydrocarbons and microplastics.

REFERENCES

Aspila, K. I., Agemian, H., Chau, A.S.Y. 1976. A semi-automated Method for the determination of inorganic, organic and total phosphate in sediments. *Analyst*, 101: 187-197.

Bohm, E. L. 1973. Studies on the mineral content of calcareous algae. *Bulletin of Marine Science,* 23: 177–190.

Burone, L., Muniz, P., Pires-Vanin A. S. and Rodrigues, M. 2003. Spatial distribution of organic matter in the surface sediments of Ubatuba Bay (Southeastern – Brazil). *Annals of the Brazilian Academy of Sciences*, 75(1): 77-90.

Buscail, R., Pocklington, R., C. Germain, C. 1995. Seasonal variability of the organic matter in a sedimentary coastal environment: sources, degradation and accumulation (continental shelf of the gulf of lions, northwestern Mediterranean Sea). *Continental Shelf Research*, 15(7): 843-869.

Carreira, R., Wagener, A., Readman, J., Fileman, T., Macko, S., Veiga, A. 2002. Changes in the sedimentary organic carbon pool of a fertilized tropical estuary, Guanabara Bay, Brazil: an elemental, isotopic and molecular marker approach. *Marine Chemistry*, 79(3-4): 207-227.

Correll, L. D., 1998. The role of phosphorus in the eutrophication of receiving waters: a review. *J. Environ. Qua,* 27(2): 61-266

Cotano, U., Villate, F. 2006. Anthropogenic influence on the organic fraction of sediments in two contrasting estuaries: A biochemical approach. *Marine Pollution Bulletin,* 52: 404–414.

Danovaro, R., Fabiano, M., Della Croce, N. 1993. Labile organic matter and microbial biomasses in deep-sea sediments (Eastern Mediterranean Sea). *Deep-Sea Research*, 40:953–965.

Dell'Anno, A., Mei, M. L., Pusceddu, A., Danovaro, R. 2002. Assessing the thropic state and eutrophication of coastal marine systems. A new approach based on the biochemical composition of sediment organic matter. *Marine Pollution Bulletin*, 44: 611–622.

Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A., Smith, F. 1956. Colorimetric method for determination of sugars and related substances. *Analytical Chemistry,* 28: 350-356.

Fakhri, M., Abboud-Abi Saab, M., Khalaf, G., Najjar, E. 2013. Variations of sediments characteristics in coastal hot spots of the Lebanese marine area. INOC – IIUM-International Conference, Kuantan- Malaysia, 28-30.

Fakhri, M., Abboud - Abi Saab, M., Romano, J. C., Mouawad, R. 2008. Impact of phosphate factory discharges on the sediments biological characteristics of Batroun marine area (North Lebanon). International Conference on "Monitoring and Modelling of Marine Pollution". INOC-INCO, 1-3 December 2008 Kish Island Islamic Republic of Iran., 53.

Fichez, R. 1991. Suspended particulate organic matter in a Mediterranean Submarine cave. *Marine Biology*, 108: 167-174.

Fichez, R. 1991. Composition and fate of organic matter in submarine cave sediments; implications for the biogeochemical cycle of organic carbon. *Oceanologica acta*, 14(4): 369-377.

Furtado, V., Mahiques, M. 1989. Distribution of sediments in the northern coast and continental shelf of the state of Sao Paulo. Academy of Science of the state of Sao Paulo, 1: 20-29.

Galois, R., Blanchard, G. Seguignes, M., Huet, V., Lucette, J., 2000. Spatial distribution of sediment particulate organic matter on two estuarine mudflats: a comparison between Marennes-Oléron Bay (France) and the Humber estuary. *Continental Shelf Research,* 20: 1199-1217.

Garcia-Rodriguez, F., PuertoII, L., N. VenturiniI, N., PitaI, A., BrugnoliI, E., BuroneI, L., Muniz, P. 2011. Diatoms, protein and carbohydrate sediment content as proxies for coastal eutrophication in Montevideo, Rio de la Plata Estuary, Uruguay. *Brazilian journal of oceanography*, 59: 4.

Goedicke, T., Sagebiel, S. 1976. Sediment movements in Lebanese submarine canyons. *Acta Adriaticia*, 8: 115-128.

Hamdan, F., 1998. Industrial Pollution in Lebanon. Greenpeace Mediterranean, Lebanon Campaign, 1-9.

Jørgensen B., Richardson, K. 1996. Material flux in the sediment. *Coastal and estuarine studies*. American Geophysical Union, 115-135.

Karageorgis, A., Anagnostou, Ch., Sioulas, A., Elephteriadis, G., Tsirambides, A. 2004. Distribution of surficial sediments in the Southern Evoikos and Petalloi Gulfs, Greece. *Mediterranean Marine Science,* 1(1): 111-121.

Kumar, B. S. K., Sarma, V.S., Krishna, M.S., 2013. Distribution of biochemical constituents in the surface sediments of western coastal Bay of Bengal: influence of river discharge and water column properties. *Environmental Earth Science,* 69: 1033–1043.

Lazar, L., Gomoi, M.T., Boicenco, L., Vasiliu, D. 2012. Total Organic carbon (TOC) of the surface layer sediments covering the seafloor of the Romanian Black Sea Coast. *Geo-Eco-Marina*, 18: 121-132.

Lorenzen, C.J., 1967. Determination of chlororophyll and phaeopigments: spectrophotometric equations. *Limnology and Oceanog*raphy, 12: 343-346.

Lowry, O. H., Rosebrough, N. J., Farr, A. L., Randall, R. J. 1951. Protein measurement with the Folin Phenol Reagent. *The journal of biological chemistry*, 193, 265-275.

MA., 2010. Détermination du carbone organique total dans les solides: dosage par titrage. Méthode d'analyse – Centre d'expertise en analyse environnementale du Québec.

Magni, P., Abe, N., Montani, S. 2000. Quantification of microphytobenthos biomass in intertidal sediments: layer-dependent variation of chlorophyll-a content determined by spectrophotometric and HPLC methods. *La Mer*, 38: 57-63.

Marsh, J. B., Weinstein, W. J. 1966. A simple charring method for determination of lipid. *Journal of Lipid Research*, 7: 374-576.

MoE/UNDP, 2011. Climate change vulnerability and adaptation, coastal zones. Lebanon's Second National Communication.

Misic, C., Harriague, A. C. 2013. Urbanised beaches of the Ligurian coastal area (NW Mediterranean): A classification based on organic-matter characteristics and hydrolytic enzymatic activities. *Marine Environmental Research,* 87-88: 103-111.

Pinturier-Geiss, L., Méjanelle, L., Dale, B., Karlsen, D. A., 2002. Lipids as indicators of eutrophication in marine coastal sediments. *Journal of Microbiological Methods,* 48: 239-257.

Plante, R., Plante-Cuny, M., Reys, J. 1986. Photosynthetic pigments of sandy sediments on the north Mediterranean coast: their spatial distribution and its effect on sampling strategies. *Marine Ecology*, 34: 133-141.

Pusceddu, A., Sara, G., Mazzola, A., Fabiano, M. 1997. Relationships between suspended and sediment organic matter in a semi-enclosed marine system: the Stagnone di Marsala sound (Western Sicily). *Water, Air & Soil Poll*ution, 99: 343-352.

Renjith, K. R., Joseph, M. M., Ghosh, P., Rahman, K., Kumar, C. S., kumar, N., 2013. Biogeochemical facsimile of the organic matter quality and trophic status of a micro-tidal tropical estuary. *Environmental Earth Science*, 70: 729–742.

Sane, E., Isla, E., Gerdes, D., Montiel, A., Gili, J.-M., 2012. Benthic macrofauna assemblage sand biochemical properties of sediments in two Antarctic regions differently affected by climate change. *Continental Shelf Research,* 35: 53–63.

Silva, F. S., 2011. Bioavailability of organic matter in the superficial sediment of Guanabara Bay, Rio de Janeiro, Brazil. *Anu. Inst. Geocienc.* 34(1): 52-63.

UNEP. 1995. Manual for the geochemical analyses of marine sediments and suspended particulate matter, Reference Methods for Marine Pollution Studies. 63: 1-85.

Youssef, D.H., El-Said, G.F., Shobier, A.H., 2014. Distribution of total carbohydrates in surface sediments of the Egyptian Mediterranean coast, in relation to some inorganic factors. *Arabian Journal of Chemistry*, 7(5): 823-832.