IMPACT OF PHOSPHOGYPSUM AND OTHER FACTORY EFFLUENTS ON MEIOFAUNA COMMUNITIES OF BATROUN COASTAL REGION

R. Mouawad [1, 2], G. Khalaf [1] and Y. Salameh [2]
[1] National Council for Scientific Research, National Center for Marine Sciences,
P.O. Box: 534, Batroun, Lebanon
[2] Lebanese University, Faculty of Sciences II, Fanar, Lebanon
rita_mouawad@hotmail.com

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ABSTRACT

Meiofauna assemblages were sampled in summer 2007 and winter 2008 at ten stations along Batroun coastal region in North Lebanon, offshore from the fertilizer factory.

A survey of the major meiofaunal taxa was made in order to study the impact of chemical discharges (phosphogypsum) on meiofaunal population composition and density. There were significant changes in the community density and composition in the stations located in front of the plant (S5 to S8). Total meiofauna abundance was the lowest in the stations located in front of the plant, ranging between 8.7 ± 5.5 (S6) and 161.1 ± 35.3 (S5) individuals 10 cm^{-2} in August and between 10.5 ± 9.4 (S6) and 42.3 ± 31.2 (S5) individuals 10 cm^{-2} in January. The highest densities were recorded at the stations located at the south and the north of the discharge pipe (S1 to S4 and S9 to S10). At these stations total meiofauna abundance ranged between 344 ± 68.4 and 827.1 ± 58.2 individuals 10 cm^{-2} in August and 167.6 ± 31.3 and 758.6 ± 274.2 in January. Nematodes, followed by copepods exhibited the greatest densities among the 22 meiofauna taxa recorded at the 10 stations.

The diversity within meiofaunal assemblages was low at the stations located near the plant (2 to 6 taxa) and higher at the other stations (9 to 19 taxa).

Keywords: meiofauna, chemical pollution, North Lebanon, Mediterranean Sea

INTRODUCTION

Meiobenthic communities are composed of animals of small size which have short generation times (mostly days to weeks) and *in situ* direct benthic development *i.e.* with no planktonic larval stage.

Meiofauna and especially nematodes have several advantages for environmental bioassessment: (a) they occur in large numbers; (b) they live in the sediment; (c) because of their permeable cuticle they are in direct contact with the capillary water; (d) they do not directly migrate from stressful conditions; (e) many species are extremely tolerant of disturbance and harmful chemicals; (f) many species have a short generation time and react quickly to changes in the environment. The usefulness of nematodes in biomonitoring studies was shown by several lotic and marine nematologists (***e.g.*** Bongers & Van De Haar, 1990; Neira *et al.,* 2001). These features make meiofauna the appropriate animals for pollution studies (Gray & Ventilla, 1971; Somerfield &Warwick, 1994; Austen & McEvoy, 1997), and one of the most popular tools for detecting the ecological effects of different sources of impact in subtidal sandy shores (Gee *et al.,* 1992; Mazzola *et al.*, 2000; Neira *et al.,* 2001).

In Lebanon, little attention has been paid to the usefulness of meiofauna assemblages in pollution studies. Some investigations were performed to study the effect of sewage discharges on sandy beach meiofauna (Gowing & Hulings, 1976; Mouawad, 2005). However, there is no study concerning the impact of chemical discharges and especially the phosphogypsum on meiobenthic assemblages in Lebanon and in the Levantine basin.

The aim of this study is to investigate the impact of phosphogypsum on the composition, densities and distribution of subtidal meiofauna.

MATERIALS AND METHODS

Study area and sampling strategy

Ten stations (S1 to S10) located on the northern part of the Lebanese coast opposite to Selaata chemical plant and Al-Jaouz River were investigated (Figure 1, Table 1). Sampling was done in August 2007 and January 2008 to cover the periods of high and low organic input into the sediment.

Two transects were sampled for meiofauna, sediment and chemical analysis. The first located along the coastline (S1 to S8) and the second perpendicular (S9, S10) to the coast. Three samples of meiofauna were collected at each point, using transparent plexi cores (sampling surface area 10 cm^2) at water depths varying between 4 and 24 m. Samples were immediately fixed with 4 % buffered formaldehyde (Heip *et al*.,1985; Vincx, 1996). An additional sample was collected at each sampling station using the same core sampler for granulometric analyses. Water samples were collected for nitrate, phosphate and salinity analyses at each sampling point.

Laboratory treatment

In the laboratory, meiofauna samples were rinsed with a gentle jet of freshwater over a 1 mm sieve to exclude macrofauna, decanted over a 40 µm sieve, centrifuged 3 times with Ludox HS40 (specific density 1.18) and stained with Rose Bengal.

Sediment was analysed using a Malvern mastersizer laser sediment particle analyzer.

Orthophosphate was analysed by the colorimetric method of Murphy and Riley (1962), and nitrate by the method of Bendschneider and Robinson (1952).

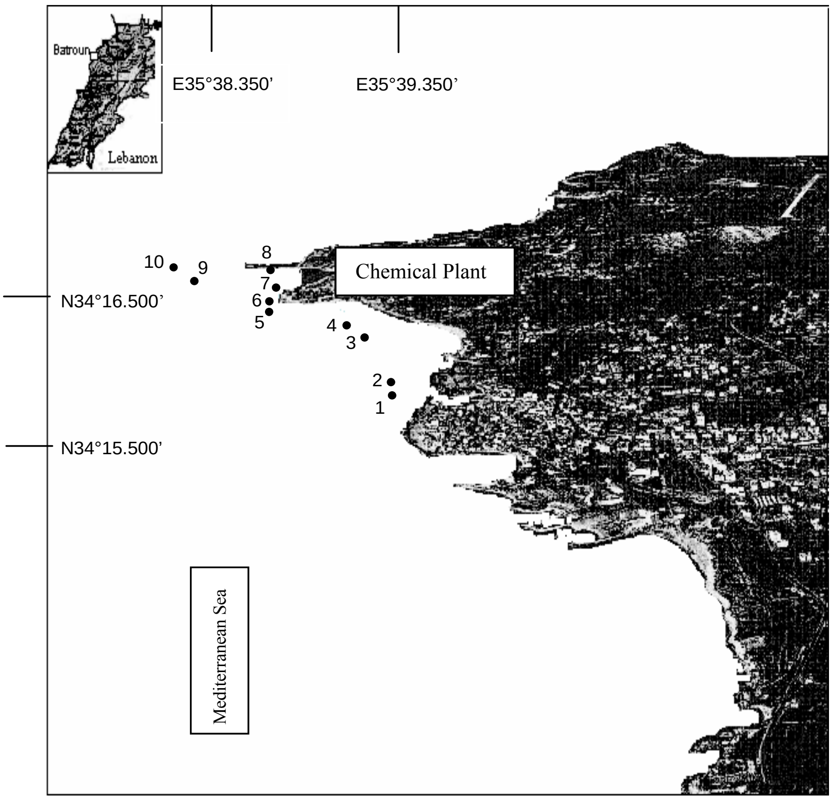


Figure 1. Location of the 10 stations investigated in Batroun coastal area.

RESULTS

The environmental variables

Sediment analyses

All the sediment fractions were present in the 10 investigated stations except for the gravel which was absent in S1 to S8 and present only in S9 and S10 (Table 2).

The clay and silt fraction (0 - 63 µm) and the very fine and fine fraction (63 - 250 µm) were found to be dominant in the stations located in front of the plant from S4 to S7. This small grain size corresponds mainly to the discharges of gypsum which form a white layer covering the sediment.

The sediment in S1 and S2 located in front of El Jaouz river mouth is composed mostly of fine and medium sand, while the stations located at the north of the plant S9 and S10 are dominated by coarse sediment (78 and 75.6 %).

TABLE 1

Description and Coordinates of the 10 Investigated Stations

Stations	Coordinates	Bottom type and Depth (m)	Location
S01	N 34° 15,533' E 35° 39,361'	Rocky with big areas of sand, 10 m	50 m from the exit of the harbor of Batroun
S02	N 34° 15,684' E 35° 39,357'	Rocky with big areas of sand, 10.5 m	125 m far from the coast
S03	N 34° 16,003' E 35° 39,339'	Sandy, 6 m	140 m in front of the river mouth and 400 m from the south wall of the plant
S04	N 34° 16,160' E 35° 39,304'	Sandy, 6 m	100 m far from the coast and 200 m from the discharge at the south wall of the plant
S05	N 34° 16,377' E 35° 39,119'	Sand and gravel, 11m	60 m in front of the west wall of the plant and to the south of cooling discharge
S06	N 34° 16,440' E 35° 39,102'	White layer of gypsum and gravel, 6 m	50 m in front of the west wall of the plant and to the north of cooling discharge
S07	N 34° 16,579' E 35° 39,132'	Rocky with small areas of sand, 5 m	100 m in front of the principal discharge, north side of the plant
S08	N 34° 16,748' E 35° 39,214'	Rocky with large areas of sand, 4 m	50 m south of the jetty and 100 m from the coast
S09	N 34° 16,672' E 35° 38,734'	Rocky with small areas of sand, 16 m	600 m offshore from station S7
S10	N 34° 16,834' E 35° 38,370'	Rocky with large areas of fine gravel, 24 m	1200 m offshore from station S7

TABLE 2

Percentage of the Different Grain Size Fractions in the Sampling Stations (S1-S10)

Station	Silt+Clay	Very fine and fine sand	medium sand	coarse sand	gravel
S1	0.5	15.4	59.4	24.8	0.0
S2	3.2	50.5	42.4	3.9	0.0
S3	2.0	20.5	63.0	14.5	0.0
S4	21.8	41.2	31.6	5.4	0.0
S5	30.5	53.1	16.4	0.0	0.0
S6	99.1	0.9	0.0	0.0	0.0
S7	70.0	29.0	1.0	0.0	0.0
S8	4.7	37.9	53.4	5.1	0.0
S9	2.9	2.4	16.7	78.0	0.1
S10	1.4	0.4	4.8	75.6	17.7

Salinity

The lowest values of salinity were recorded in the stations S1, S2 located in front of Nahr El Jaouz River mouth and to the north in S3 and S4 (Table 3). These values fluctuate between 38.65 and 38.76 in August and between 38.11 and 38.42 in January. An increase in salinity was registered in the north far from the river mouth (S5 to S10) with values fluctuating from 39.35 to 39.79 ‰ in August and from 39.12 to 39.17 ‰ in January.

Nitrates

Nitrate concentrations are influenced by the river flow in January. For this reason, the highest concentrations were recorded in the stations located in front of the river mouth (0.76 ± 0.06 in S1 to 1.09 ± 0.03 in S3). However, in August the river flow decreased and nitrate concentrations were almost similar in all the stations except for station S8 located 100 m from the coast (Table 3).

Phosphates

The variation in phosphate concentrations is plotted in figure 2. The highest values were recorded in stations S4 to S7 located in front of the plant and influenced by the phosphogypsum discharges. These stations show the maximum mean values recorded in August and January. Phosphate concentrations in these stations fluctuated from 4.20 ± 1.3 to 5.65 ± 1.5 in August and from 4.65 ± 0.15 to 5.54 ± 0.81 in January. The lowest concentrations were recorded in stations S1, S2, S9 and S10 situated far from the plant (Table 3).

TABLE 3

Hydrological Parameters of the Sampling Stations in August and January
Means ± standard errors are given

	Aug-07			**Jan-08**		
	PO_4^{3-} (μ-gat./L)	**NO_3^- (μ-gat./L)**	**S (‰)**	**PO_4^{3-} (μ-gat./L)**	**NO_3^- (μ-gat./L)**	**S (‰)**
S1	0.76±0.52	0.57±0.11	38.65±0.43	0.08±0.02	0.76±0.06	38.11±0.52
S2	0.95±0.62	0.49±0.22	38.68±0.66	0.04±0.01	0.93±0.02	38.22±0.36
S3	1.73±1.20	0.41±0.10	38.73±0.72	0.12±0.03	1.09±0.03	38.25±0.52
S4	4.20±1.3	0.45±0.21	38.76±0.13	4.65±0.15	0.53±0.01	38.42±0.59
S5	4.60±1.8	0.51±0.22	39.71±022	5.15±0.26	0.54±0.01	39.12±0.22
S6	5.65±1.5	0.46±0.09	39.79±0.35	5.44±0.33	0.38±0.03	39.15±0.25
S7	5.24±0.42	0.33±0.06	39.58±0.68	5.54±0.81	0.56±0.05	39.17±0.66
S8	3.23±0.33	1.95±0.11	39.35±0.72	4.79±0.33	0.25±0.03	39.11±0.68
S9	0.16±0.8	0.83±0.23	39.46±0.45	0.31±0.02	0.06±0.01	39.06±0.72
S10	0.27±0.1	0.53±0.32	39.50±0.62	0.19±0.01	0.08±0.01	39.14±0.59

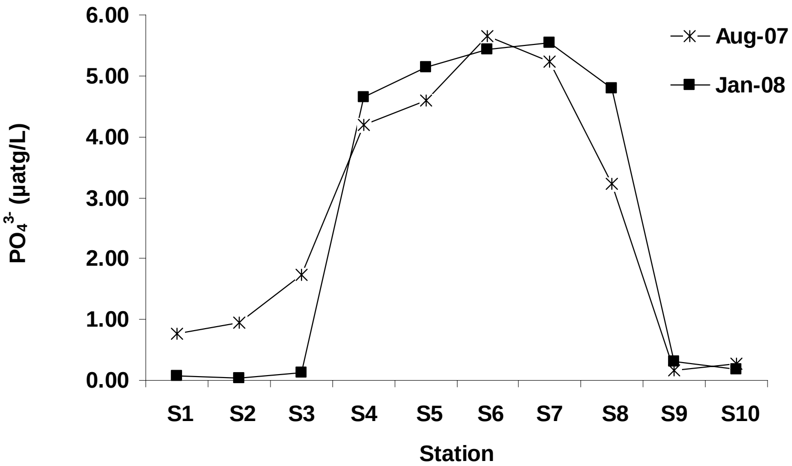


Figure 2. Variation of phosphate concentrations at each sampling station.

Meiofauna community structure

Mean meiofaunal densities of the most important taxa are shown in Table 4.

The total meiofauna densities varied significantly between polluted and unpolluted stations (Kruskal-Wallis *H*-Test; $p < 0.05$). The seasonal variation of the mean abundance of meiofauna was significant at all locations (Kruskal-Wallis *H*-Test; $p < 0.05$) except for the polluted stations S6 and S7 ((Kruskal-Wallis *H*-Test; $p = 0.0522$).

In August, the highest densities and highest number of taxa were observed at the unpolluted stations located far from the plant discharges, in the south (S1 to S4) and the north perpendicular to the coast and at important depths (S8 and S10). The mean abundance was 489 ind./10 cm^2. The densities of total meiofauna at these unpolluted stations fluctuate from 344.1 ± 68.4 to 827.1 ± 58.2. Nematodes were the most abundant group (24 % - 89 %) followed by copepods (11% - 47%) and polychaetes (7 % - 37 %).

In the polluted stations (S4 to S7) the meiofauna densities were the lowest, with a mean abundance of 66 ind./10 cm^2 (Table 3, Figure 3). The densities ranged from 9 ± 5.9 to 161 ± 35.3 ind./10 cm^2 (table 4). Nematodes were the dominant taxon in the disturbed stations with 48 to 97 %, followed by copepods and polychaetes.

In January, the mean meiofauna abundance in the unpolluted and polluted stations (340 and 23 ind./10 cm^2 respectively) were lowest than in August (489 and 66 ind./10 cm^2 respectively).

At the unpolluted stations, the meiofauna densities in January ranged from 63 to 759 ind./10 cm^2 and from 11 to 42 in the stations located in front of the plant. The number of taxa was 7 to 20 and 2 to 9 respectively at the unpolluted and polluted stations. Nematoda was the dominant taxon in all the investigated stations (20 % - 97 %) except for station S10 (7 %), followed by copepods (5 - 51 %).

TABLE 4

Mean, Minimum and Maximum Abundance, Number of Taxa at the Unpolluted (North and South of the Plant) and the Polluted Stations (in front of the Plant)

	Unpolluted stations		Polluted stations	
	Aug-07	Jan-08	Aug-07	Jan-08
mean abundance (ind./10cm^2)	489	340	66	23
minimum and maximum abundance (ind./10cm^2)	344 - 827	63 - 759	9 -161	11 - 42
number of taxa	7 - 14	7 - 20	2 - 6	2 - 9

TABLE 5

Densities of the Most Important Meiofauna Taxa Recorded at the Ten Investigated Stations (Copep.: Copepoda)

Aug-07						
	Nematoda	Copep.+Nauplii	Polychaeta	Turbellaria	Others	Total meiof.
S1	169.7 ± 73.4	51.3	112.4	5.7	5.0	**344.1±68.4**
S2	329.9±106.5	196.4	38.5	14.3	5.8	**584.9±147**
S3	344±28	46.9	13.0	4.1	16.3	**424.3±14.7**
S4	739.1±66.7	45.9	29.6	9.8	2.7	**827.1±58.2**
S5	149.4±27.6	3.8	4.3	3.2	0.3	**161.1±35.3**
S6	8.5±5.9	0.0	0.3	0.0	0.0	**8.7±5.5**
S7	13.4±4.3	4.5	3.4	5.5	1.0	**27.8±7.8**
S8	383.6±26.9	13.2	2.8	0.0	1.3	**401.0±14.7**
S9	37.4±36.9	44.9	57.5	0.0	14.1	**153.9±123.5**
S10	107.1±35.2	165.5	66.0	4.1	11.3	**354.2±62.4**
Jan-08						
	Nematoda	Copep.+Nauplii	Polychaeta	Turbellaria	Others	Total meiof.
S1	330.4±140.6	260.2	24.8	45.0	52.4	**712.8±241.8**
S2	269.7±75.8	384.3	15.1	58.1	31.4	**758.6±274.2**
S3	32.1±21.2	16.3	5.9	2.7	6.0	**63.0±26.1**
S4	172.3±286.5	7.4	3.6	1.8	6.0	**191.0±303.5**
S5	31.6±15.7	1.3	0.7	5.3	3.3	**42.3±31.2**
S6	7.4±4.9	1.6	0.0	0.9	0.6	**10.5±9.4**
S7	20.4±29.3	1.1	0.0	1.9	0.4	**23.8±33.6**
S8	13.7±18.8	0.0	0.4	0.0	0.0	**14.1±18.4**
S9	42.3±40.4	36.3	8.3	0.8	126.7	**214.3±84.7**
S10	7.1±3.1	42.7	35.5	0.0	12.9	**98.2±88.7**

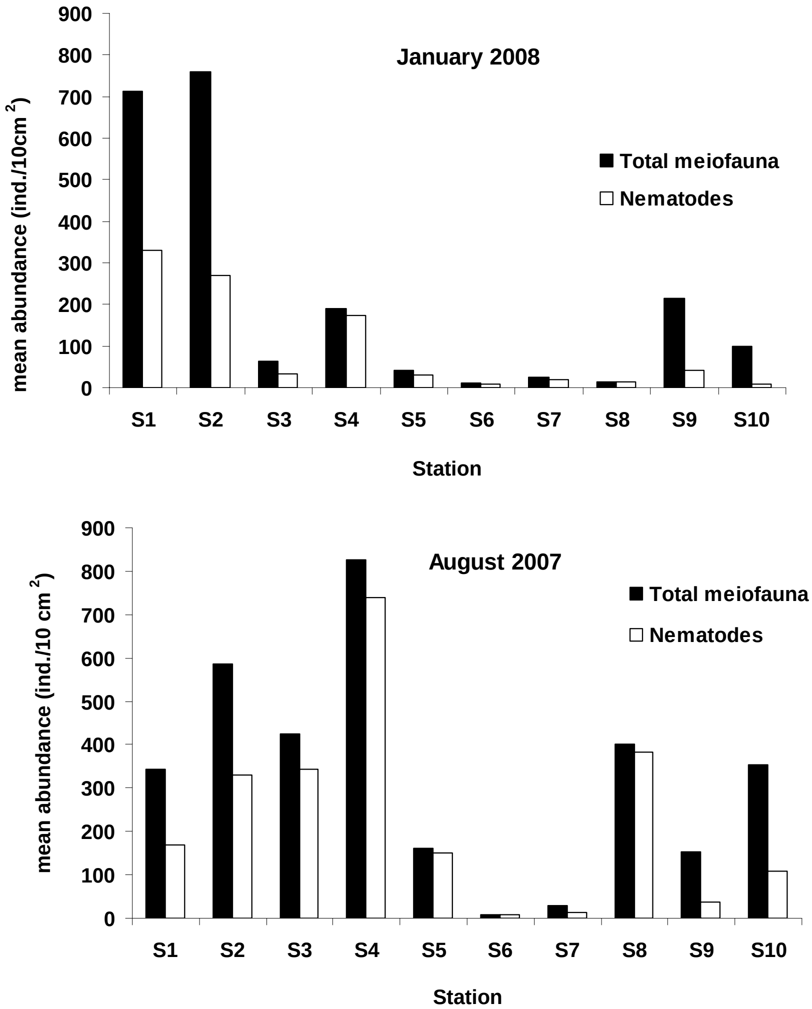


Figure 3. Mean abundance of the total meiofauna and nematodes group found in August 2007 and January 2008 at the investigated sampling stations.

In general, meiofauna reached the highest densities in August in the stations located far from the plant emmission point, and near the river mouth. The lowest meiofauna densities occurred in January (except for stations S1 and S2) and at locations in front of the plant emissary (Tables 3, 4 and Figure 3).

DICUSSION AND CONCLUSION

Even though the literature abounds with studies of influence of pollution on meiofauna assemblages from sandy beaches and coastal regions all over the world, direct comparison with the current study is limited, due to fundamental differences in pollutants nature (phosphogypsum). For example influence of heavy metals, sewage discharges, fertilizers and other pollutants were studied but the current study is one of the rare studies concerning the impact of phosphogypsum sediment on meiofauna assemblages.

The plant is the main source of orthophosphate in Batroun coastal region (Fakhry *et al.*, 2005). Orthophosphate concentrations vary significantly between the stations located in front of the plant emissary (S4 to S7) and the other sampling stations. The input appears to be almost constant in January and August except for stations located in front of the river (S1 to S3) where the orthophosphates concentrations were lower in January fluctuating from 0.018 ± 0.02 to 0.12 ± 0.03 (µgat./L) and from 0.76 ± 052 to 1.73 ± 1.20 (µgat./L) in August.

Nahr El Jaouz River increases the concentrations of nitrates in the stations located in the river plume (S1 to S3) in January, when the river flow is important. However, the amount of phosphates is low. Nahr El Jaouz River drains agricultural lands where nitrates are used as fertilizers. The nitrate mass brought yearly to Batroun seawater is estimated at $270*10^{7}$ µatg (Abboud-Abi Saab *et al.,* 1999-2002).

The impact of industrial activity of Selaata plant is considered as space limited; however the contamination impact remains at a critical level.

In the studied area, the river dilution plume and the plant discharges could be considered as the main sources of disturbance. This is confirmed by PCA analysis results where three clusters were determined corresponding to the specific loads of Al Jaouz River, Selaata chemical plant and the area located to the north, far from the effluent of the plant. The first cluster represented by the stations S5, S6 and S7 located in front of the plant are determined by three variables: salinity, silt and clay and orthophosphates (figures 4 and 5). The second cluster represented by the stations S1, S2, S3 and S4 and are determined by fine and very fine sand, nematode total meiofauna and medium sand.

The third cluster represented by the stations S9 and S10 was determined by the coarse sand.

The stations affected by the factory's effluents (first cluster, figures 4 and 5) contained higher concentrations of orthophosphates, slightly higher salinity and a finer grain size (silt and clay). The high concentrations of orthophosphates in these stations decreased the densities of meiofauna and nematodes. A significant inverse correlation ($r = -0.46$; $p<0.05$) is established between meiofauna densities and orthophosphates and between meiofauna densities and silt and clay percentage ($r = -0.49$; $p<0.05$). The high percentage of silt and clay in these stations is due to accumulation of phosphogypsum on the bottom. Darmoul and Vitiello (1980) demonstrated that the phosphogypsum creates a toxic environment (pH≈4) and thus is considered harmful for living marine organisms.

At the stations located out of the dominant influence of the chemical plant (second cluster, S1 to S4), the situation was different. These stations were characterized by the presence of high densities of meiofauna and nematodes and by fine and medium sand. The influence of the river is considerable in these stations, as indicated by the high concentrations of nitrates.

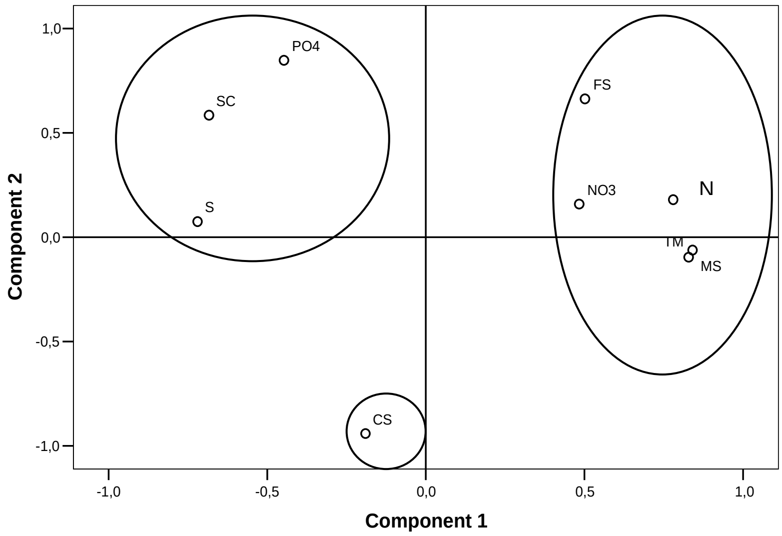
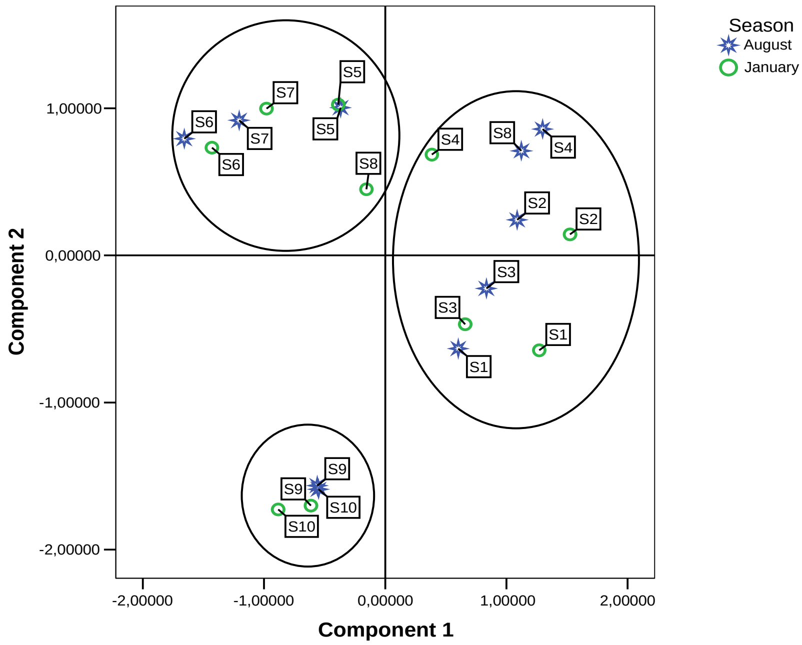


Figure 4. Plane-space of factors F1 and F2 of Principal Component Analysis (structure of variables). FS: very fine and fine sand; SC: silt and clay; MS: medium sand; CS: coarse sand; PO4: orthophosphates; NO3: nitrates; S: salinity; TM: total meiofauna; N: nematoda).

The most distant and deepest stations S9 and S10 (third cluster) were characterized by coarse sand and lower densities of meiofauna. Even though these stations are not under the plant influence, the lower densities of meiofauna could be explained by the coarse sediment fraction which is subjected to active hydrodynamics and thus present an unstable environment for meiofauna development.

PCA analysis confirms the presence of three different zones in Batroun coastal areas. The first zone located in front of Selaata chemical plant (S5, S6 and S7) and considered as a highly polluted area with sediment covered by a layer of phosphogypsum that creates a toxic environment and decrease the number of meiofauna organisms living in the sediment.

The second zone located at the south of the factory near the river plume. This area is characterized by a higher number of meiofauna organisms and lower concentrations of orthophosphates. The third zone located at the north of the plant (S9 and S10), with a coarse sand and relatively lower number of meiofauna.



Component 1

Figure 5. Plane-space of factors F1 and F2 of Principal Component Analysis (structure of stations: S1 to S10).

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