

THE USE OF SEDIMENTS TO ASSESS THE IMPACT OF SELAATA PHOSPHATE PLANT ON BATROUN COASTAL AREA (LEBANON, LEVANTINE BASIN)

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ABSTRACT

The sediments of twelve coastal stations located in Batroun marine area (North Lebanon, Levantine basin) which is subjected to the impact of Selaata phosphate fertilizers plant were studied horizontally and vertically during summer of 2003. In order to delimit the factory's spatial influence, the distribution of inorganic phosphate in surface sediments was explored and compared with orthophosphate mean concentrations in surface water. Also in order to draw a chronological history for the plant's functioning, the vertical distribution of inorganic phosphate associated with organic compounds (carbohydrates, proteins and lipids) distribution in the different levels of sediment down to 15 cm was studied.

The concentrations of inorganic phosphate varied from 597 to 2279 $\mu\text{g}\cdot\text{g}^{-1}$ in the surface sediments of the stations located out of the main outlets' influence (M1 to M6 and M12 to M13), while they were extremely high, fluctuating between 8068 and 64256 $\mu\text{g}\cdot\text{g}^{-1}$ at the stations (M7 to M10) located under the direct influence of Selaata factory. A significant positive correlation existed between the inorganic phosphate in sediments and the orthophosphate in sea water. The whole studied area was affected by phosphate emissions and was classified into 2 zones: the first one is indirectly touched by the plant's effluents and located to the south and offshore of the factory, and the second directly influenced by the plant's outputs and located to the west and west-northern side. The penetration in the different sediment levels showed that at stations located far from the plant's main outlets, there were difficulties in determining any of plant's history because of the homogeneity of phosphate and organic matter distribution associated to strong hydrodynamism. Where as the sediments of stations located in front of the west-northern outlets could elaborate and highlight part of the phosphate factory's operational history and could show that in this zone of Batroun marine area the plant's sedimentation rate had overcome that of the natural processes.

Keywords: Levantine basin, Lebanon, sediments, phosphate plant

INTRODUCTION

Lebanon is a small country of 10452 km² with a 220 km long coastline located in the heart of the Middle East at the edge of the Levantine basin. Urbanism, demographic

explosion and industries, existing on its coast, are menacing its whole marine environment, ecosystems and populations. Like most of the mediterranean countries, the industries are located at the seaside for cooling processes or in the vicinity of the ports for transportation facilities (import of raw materials and export of products). One of the biggest Lebanese industries is the Selaata phosphate fertilizers plant that was arbitrarily established in 1957 at Batroun's ancient coastal side. Daily, this plant is using more than 840 tons of phosphate rocks (Abboud-Abi Saab & Dargham, 1998) with a yearly production capacity exceeding 765 thousand tons of multiple products mainly phosphate fertilizers, and phosphoric and sulfuric acids (Yager, 2005). Most of the plant's by-products (phosphogypsum, phosphoric acid and sulfuric acid) are thrown directly into the sea without any pretreatments (Abboud-Abi Saab & Attallah, 1996). In reference to Fakhri *et al.* (2005), the Selaata chemical plant is supplying Batroun marine water with large unknown quantities of phosphate where an inverse relationship was detected between orthophosphate concentration and the distance from the factory's outlets. The discharges from the various effluents are irregular. The outflow at the factory's south wall exhibits weaker flow intensity and lower orthophosphate concentrations than the one at the west-northern side.

It would be interesting to deal with the contamination problems from this factory at benthic level, since the sediments integrate the various contaminant fluctuations. This would provide information on both, the source and the dispersion of contaminants, and a long-term integration of the environmental impact on the dynamic and complex surrounding (Birch *et al.*, 1999) by smoothing the fluctuations of different characteristics, in space and time. Indeed, sediments represent the final destination of the major part of the terrestrial compounds of natural or human origin. Their analysis (Eyre & McConchie, 1993) allows the detection of contaminants not being revealed by water analysis (Pardo *et al.*, 1990). The fate of the contaminants associated to the particles is much better determined through the study of sediment dynamics than by the study of the water column alone (Dyer, 1989; Balls, 1990).

Batroun coastal zone, which is an open sea, is not oligotrophic, as is reported for the Lebanese Sea (Abboud-Abi-Saab, 1992) and for the eastern Mediterranean Sea (Berland *et al.*, 1987; Bethoux *et al.*, 1992; Denis-Karafistan *et al.*, 1998). Batroun coastal zone is continuously fertilized with great amount of phosphate products originated from Selaata factory and it is subjected to an active hydrodynamism and to the periodic outflow of Al-Jaouz seasonal river (74 million m³ annual mean flow).

This study aims to assess the impact of Selaata chemical plant by studying the horizontal distribution of inorganic phosphate, the most representative element of the plant, in surface sediments in relation with the spatial distribution of orthophosphate in surface water. This would reveal the impact of the large amount of orthophosphate thrown in Batroun coastal water, to determine if Batroun sediments reflect what is happening in water and to follow the spatial dispersion of the plant's rejections. According to Literathy *et al.* (1987), the collection and the analysis of sediment core provide the pollution history records for the past, but the trends for the present may be assessed from the data collected regularly in the upper layers. So because of the lack of information on Selaata chemical factory and in order to reveal some of its chronological evolution, it was decided to collect sediment samples up to 15 cm deep by studying the inorganic phosphate distribution in association with the variation of organic matters concentrations (carbohydrates, lipids and proteins) where these biochemical compounds of the sedimentary matters are usually used to gather information on

the origin and the quality of deposited material (Danovaro *et al.*, 1994; Fabiano *et al.*, 1995; Pusceddu *et al.*, 1999).

MATERIAL AND METHODS

Adopted strategy

On the historical coast of Batroun city, located 55 km north of the capital Beirut, the Selaata phosphate fertilizers plant has been established since more than 50 years ago. The stations for sediment analysis were chosen according to their distance and direction from the factory. This choice was reinforced by data obtained from water analysis during 2 years of research (unpublished data).

In mid summer 2003, core samples down to 15 cm for sediment analysis were collected by diving at 13 stations (from M1 to M13). Only station M11 was not considered where no sediments were found. The area of distribution of these stations was about 3 km²: south to north from Batroun port exit (M1) till the plant jetty (M10) and east to west from the west-northern outflow (M9) to 1.5 km offshore (M13) (Figure 1, Table 1).

At each station 3 cores were taken, one for granulometry, another for inorganic phosphate analysis and a third for organic matters evaluation.

At the laboratory, the sediment columns for both inorganic phosphate and organic matters were separated by 3 cm layers and freeze-dried for analysis.

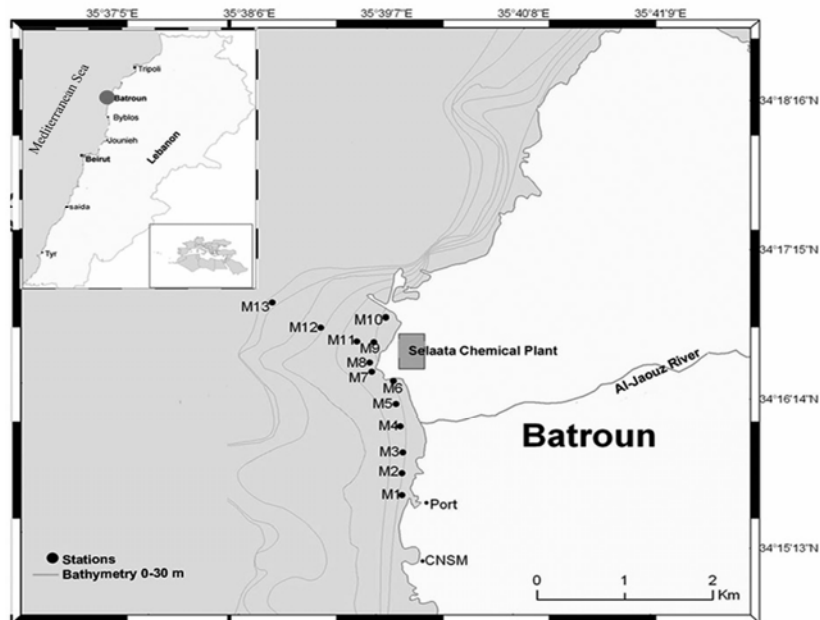


Figure 1. Sampling stations in Batroun marine area (North Lebanon).

Adopted methodologies

Determination of grain-size composition: For each station, the whole content of the core was placed in a Pyrex cup and dried in oven for 3 days at 105°C. The particle size < 0.8 mm was determined by a laser particle-measurement instrument Malvern Sizer and the fractions > 0.8 mm by simple sifting and weighing. The granulometric composition is expressed in percentage of five fractions: fine fraction (clay + silt < 63 µm), fine sand (63 µm < very fine sand + fine sand < 250 µm), mid-size sand (between 250 µm and 500 µm), coarse sand (between 500 µm and 1000 µm) and coarse fraction (>1000 µm).

TABLE 1

Geographical Coordinates, Bathymetry and Description of the Sampled Stations

Stations	Coordinates	Nature of bottom & Bathymetry	Distance from the plant
M1	N 34° 15,533' E 35° 39,361'	Rocky with large sandy surfaces; 10 m	50 m in front of Batroun port exit & 900 m to the south of plant southern outlet
M2	N 34° 15,684' E 35° 39,357'	Rocky with large sandy surfaces; 10.5 m	800 m to the south of plant southern outlet
M3	N 34° 15,824' E 35° 39,359'	Sandy dunes; 7.5 m	200 m to the south of Al-Jaouz river's mouth & 650 m to the south of plant southern outlet
M4	N 34° 16,003' E 35° 39,339'	Sandy; 6 m	100 m in front of Al-Jaouz river's mouth and 400 m to the south of plant southern outlet
M5	N 34° 16,160' E 35° 39,304'	Sandy; 6 m	200 m to the south of plant southern outlet
M6	N 34° 16,317' E 35° 39,280'	Sandy; 5 m	50 m to the south of plant southern outlet
M7	N 34° 16,377' E 35° 39,119'	Sandy with gravels; 11 m	60 m in front of the factory western outlet & 200 m to the south of the main west-northern outlet
M8	N 34° 16,440' E 35° 39,102'	Grey-white layer of phosphogypsum; 6m	50 m in front of the factory western outlet & 130 m to the south of the main west-northern outlet
M9	N 34° 16,579' E 35° 39,132'	Rocky with small sandy surfaces; 5m	100 m in front of the main west-northern outlet
M10	N 34° 16,748' E 35° 39,214'	Rocky with medium sandy surfaces; 4m	200m to the north of the main west-northern outlet
M12	N 34° 16,672' E 35° 38,734'	Rocky with patches of gravels with sand and shells; 16m	600 m in front of the main west-northern outlet
M13	N 34° 16,834' E 35° 38,370'	Rocky with patches of gravels with sand and shells; 24m	1500 m in front of the main west-northern outlet

Measurement of inorganic phosphate: Inorganic phosphate in sediments was measured according to Aspila *et al.* (1976) method, where 0.3 g of freeze-dried crushed sediments are placed in 10 cm³ porcelain cups. The powder is mixed with 50 ml of hydrochloric acid (HCl) 1N in a 100 ml Erlenmeyer and the mixture is agitated for 18 hours at room temperature. 10 ml of each extract are centrifuged for 5 minutes at 2000 rpm. The clarified extract is diluted 10 times and its inorganic phosphate content is measured according to Murphy and Riley (1962) colorimetric method. This method depends on the addition of ammonium molybdate to the diluted extract which leads to the formation of a complex that is reduced by ascorbic acid in the presence of the catalyst potassium antimonyl tartrate. The reduced form has a blue colour that is absorbed at a wavelength of 885 nm, using a spectrophotometer type Hellios γ .

Measurements of organic matters: In this paper organic matters as the sum of the three labile compounds: carbohydrates, proteins and lipids abbreviated are called (CPL).

Measurements of total lipids: The total lipids in sediments were extracted by the slightly modified method of Bligh and Dyer (1959). After extraction, they were measured by a spectrophotometer at a wavelength of 375 nm according to the charring method of Marsh and Weinstein (1966).

Measurements of proteins: Proteins were measured by a spectrophotometer at a wavelength of 700 nm in reference to the method of Lowry and Rosebrough (1951).

Measurements of carbohydrates: Carbohydrates (soluble and non soluble) were measured by spectrophotometer at a wavelength of 490 nm according to the slightly modified method of Dubois *et al.* (1956).

RESULTS

Sediment granulometry at the different sampling stations

Sediment grain composition is summarized in Figure 2. The sediments of stations (M1 to M6) located to the south of the factory are characterized by the dominance of the fine and medium size sand. The sediments of stations (M7 to M9) located to the west side of the plant are characterized by the fine fraction dominance. The sediments of both stations located offshore (M12 and M13) are mainly composed of the coarse fraction.

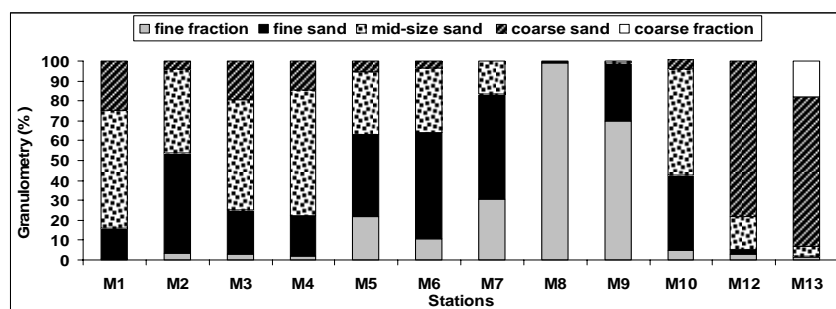


Figure 2. Sediment granulometry at each sampling station in Batroun marine area.

Horizontal distribution of inorganic phosphate Batroun sediments

The concentrations of inorganic phosphate in surface sediments of stations (M1 to M6) and (M12 to M13) are represented by Figure 3a while those of stations (M7 to M10) are illustrated in Figure 3b.

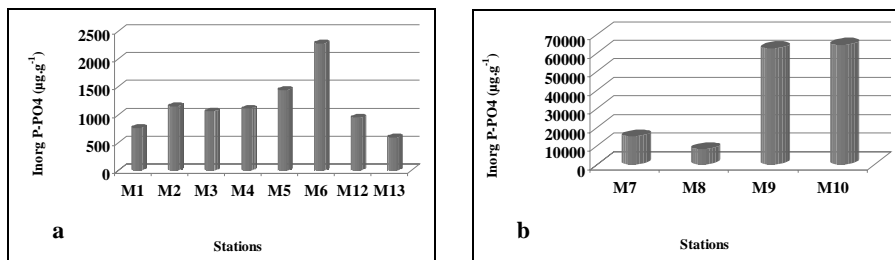


Figure 3. Distribution of inorganic phosphate in surface sediments.
a- Stations (M1 to M6) and (M12 to M13). b- Stations (M7 to M10).

They ranged between a minimum of 768 µg.g⁻¹ at station M1, in front of Batroun port exit, to a maximum of 2279 µg.g⁻¹ at station M6, in front of the factory’s southern wall, with a light increase at M2 (1156 µg.g⁻¹) compared to the two following stations, M3 (1062 µg.g⁻¹) and M4 (1111 µg.g⁻¹). The sediments of stations exposed to the west-northern effluents showed very high concentrations. At station M7, the concentration was 15050 µg.g⁻¹, almost the double of that measured in M8 sediments (8068 µg.g⁻¹) (particular sediments composed of 99% of fine fraction). The maximum concentrations were found in M9 and M10 sediments (62375 and 64256 µg.g⁻¹ respectively). In the furthest stations, M12 and M13, the concentrations were 952 and 597 µg.g⁻¹ respectively, similar to those measured in the sediments of stations close to the port and the river.

Vertical distribution of inorganic phosphate in the different levels of sediments

The vertical distribution of inorganic phosphate in sediments down to 15 cm depth is illustrated in Figure 4a for stations (M1 to M6) and (M12 to M13) and in Figure 4b for stations (M7 to M10).

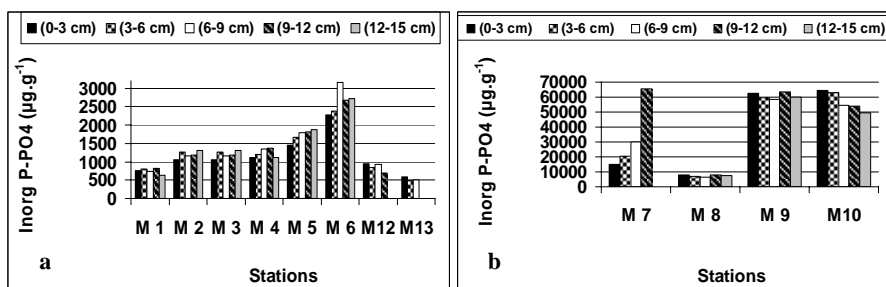


Figure 4. Vertical distribution of inorganic phosphate (µg.g⁻¹).
a- Stations (M1 to M6) and (M12 to M13). b- Stations (M7 to M10).

Inorganic phosphate concentrations did not vary much through sediment column in the stations located south of the factory. The same situation was observed at both furthest stations, M12 and M13. At stations M1, M12 and M13, the concentrations fluctuated between 483 and 951 $\mu\text{g.g}^{-1}$ along sediment core. While at stations M2, M3, M4 and M5, the concentrations varied from 1062 to 1865 $\mu\text{g.g}^{-1}$. At station M6, the nearest to the factory's south outlet, the concentrations fluctuated between 2279 and 3149 $\mu\text{g.g}^{-1}$. In all sediment levels of these stations, the distribution of phosphate was not homogenous, while the stations located under the direct influence of the west-northern outlets showed very high concentrations all along the sediment core. At station M7, the concentrations increased from the upper level (0-3cm) (15050 $\mu\text{g.g}^{-1}$) till the lowest one (12-15 cm) (65501 $\mu\text{g.g}^{-1}$). In the different levels of station M8, the concentrations were almost similar, between (6449 $\mu\text{g.g}^{-1}$) at level (6-9 cm) and (8208 $\mu\text{g.g}^{-1}$) at level (9-12 cm). The same situation was observed in the sediments of station M9 with one difference that the concentrations were much higher and they varied between 58570 $\mu\text{g.g}^{-1}$ at level (6-9 cm) and 63410 $\mu\text{g.g}^{-1}$ at level (9-12 cm). In contrary to station M7, station M10 showed a decline in phosphate concentrations from level (0-3 cm) (64256 $\mu\text{g.g}^{-1}$) till level (12-15 cm) (49313 $\mu\text{g.g}^{-1}$).

Vertical distribution of organic matters in the different levels of sediments

The vertical distribution of organic matters (CPL) is represented by Table 2. South to the factory, the CPL concentrations fluctuated arbitrarily throughout the sediment core. At stations M1, M2 and M3, they varied between 0.51 and 0.81 $\mu\text{g.g}^{-1}$, whereas at station M4 they varied tightly between 0.37 and 0.46 $\mu\text{g.g}^{-1}$. At station M5 they ranged between 0.42 $\mu\text{g.g}^{-1}$ at level (9-12cm) and 0.79 $\mu\text{g.g}^{-1}$ at level (6-9cm). At station M6, the concentrations were between 0.70 and 1.21 $\mu\text{g.g}^{-1}$. At the furthest stations M12 and M13, the concentrations varied between 0.30 and 1.42 $\mu\text{g.g}^{-1}$.

TABLE 2

Vertical Distribution of Organic Matters (CPL) ($\mu\text{g.g}^{-1}$) in Batroun Sediments

CPL ($\mu\text{g.g}^{-1}$) in sediment levels Stations	0-3cm	3-6cm	6-9cm	9-12cm	12-15cm
M1	0.79	0.65	0.59	0.62	0.67
M2	0.66	0.77	0.67	0.64	0.81
M3	0.68	0.59	0.51	0.61	0.64
M4	0.42	0.45	0.45	0.46	0.37
M5	0.67	-	0.79	0.42	0.48
M6	0.73	0.84	1.21	0.95	0.70
M7	1.06	-	1.24	1.23	-
M8	1.54	1.08	1.23	1.14	1.09
M9	2.46	2.59	1.84	1.72	1.24
M10	0.63	0.63	0.44	0.42	0.43
M12	1.26	0.38	0.92	1.09	-
M13	1.42	0.3	0.86	-	-

The vertical distribution of CPL in the sediments of stations directly influenced by the west-northern outlets was more regular. At station M7, the concentrations were $1.06 \mu\text{g.g}^{-1}$ at level (0-3 cm) and $1.24 \mu\text{g.g}^{-1}$ at both levels (6-9cm) and (9-12cm). At station M8, with particular fine granulometry, the CPL contents were high in the first level ($1.54 \mu\text{g.g}^{-1}$), while they fluctuated tightly between $1.08 \mu\text{g.g}^{-1}$ and $1.23 \mu\text{g.g}^{-1}$ in the lowest ones. At station M9, the sediments showed a clear rupture between the first 6 cm and the rest of the core where the concentrations were 2.46 and $2.59 \mu\text{g.g}^{-1}$ at levels (0-3cm) and (6-9cm) respectively, while at the lowest levels they were 1.84 , 1.72 and $1.24 \mu\text{g.g}^{-1}$ respectively. The sediments at station M10 showed lower values than those at station M9 but with almost the same distribution. In the first 6 cm, CPL concentration was $0.64 \mu\text{g.g}^{-1}$, while at lower levels the concentrations fluctuated tightly around $0.43 \mu\text{g.g}^{-1}$.

DISCUSSION

Inorganic phosphate in Batroun surface sediments

The distribution of phosphate concentrations in surface sediments allowed us to divide the studied area of Batroun coastal region into two different zones: the first one covering the stations located to the south of the factory (M1 to M6) and the most distant ones (M12 and M13), and the second zone including the stations (M7, M8, M9 and M10) directly affected by the factory's west-northern outlets. In the first group of stations, the concentrations of inorganic phosphate were very low compared with those measured in the sediments of the stations located to the west-northern side of the factory (M7 to M10). The phosphate concentrations have increased progressively while proceeding from the fishing port exit (M1) till the southern effluent (M6). The concentrations measured in the surface sediments of the second group of stations (M7 to M10) were extremely high, when compared with strongly phosphate contaminated zones in the Mediterranean Sea; for example, inorganic phosphate contents in the surface sediments of Gabès bay (Tunisia) which were under the influence of Gabès phosphate fertilizers factory varied between 225 and $6650 \mu\text{g.g}^{-1}$, according to the distance from the effluents (Darmoul *et al.*, 1980).

It was found that there is a close relationship between sediment and water phosphate concentrations. At both stations, M9 and M10, the high concentrations corresponded to the high orthophosphate averages found in sea water (Fakhri *et al.*, 2005). This was marked by a strong positive relation between phosphate concentrations in sediments and orthophosphate averages in sea water at the same stations ($r=0.97$; $P<0.001$; $k=10$) (Figure 5). Nevertheless, this relation is determined by the extreme values measured at both stations M9 and M10, but if the data collected from the stations is only compared with low concentrations of inorganic phosphate in sediments (M1 to M6 and M12 to M13) (Figure 6), it can be noted that such a relationship still holds strong.

The persistence of this correlation, even after discarding the stations that are directly influenced by the factory (M7 to M10), can only be explained by the general contamination of the studied area by the high level of orthophosphate released from the different outlets.

The contamination was also related to the distance from the source and to the general hydrodynamic regimes of the area or to the rhythm of functioning of each effluent. As a general notification, the stations where sea water was the richest in dissolved phosphate presented the sediments with the highest contents of inorganic phosphate. It is known that the

sediments absorb additional phosphate as the concentration in water increases (Balasubrahmanyam, 1961).

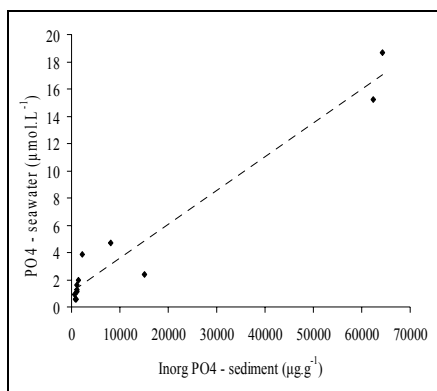


Figure 5. Correlation between phosphate surface sediment concentrations and mean orthophosphate concentrations in sea water in stations (M1 to M13) ($r=0.97$; $P<0.001$; $k=10$).

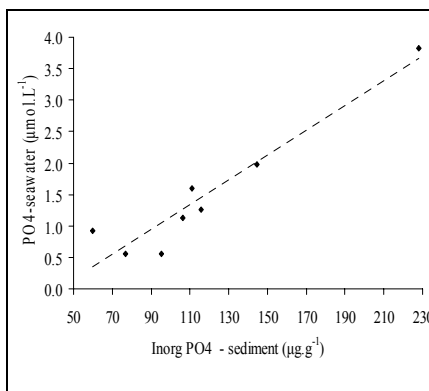


Figure 6. Correlation between phosphate surface sediment concentrations and mean orthophosphate concentrations in sea water at M1 to M6 and M12 to M13 stations ($r=0.95$; $P<0.001$; $k=6$).

The problem that is facing Batroun marine area is the dissemination of phosphate from the factory and their storage in the sediments. The grain-size distribution in the sediments of the stations located close to the factory was different (Figure 2). M8 and M9 stations were rich in fine fraction, while M10 was not. However, both stations M9 and M10 were, by far, the richest in inorganic phosphate. Whereas station M8 which is the richest in fine fraction (99% of its sediment composition) represented only 13% of the inorganic phosphate concentrations found in the sediments of stations M9 and M10.

Batroun marine area was strongly affected by the continuous and irregular release of phosphate from the Selaata factory. The benthic zone was more contaminated than the pelagic one. This is due to the fact that the sediments act as an integrator. Through time, it accumulates substances occurring in water column. Even though the average concentrations of phosphate in the stations located far from the factory's main outlets were weak, but they were strongly present in the sediments. The sediments of the stations located close to the outlets showed very high concentrations of phosphate following closely what was happening in the sea water. It was demonstrated (Eyre & Mc Conchie, 1993) that phosphate accumulation in the sediments may reach levels that push the sediments to act as a secondary source of contamination. One could then assume that Batroun sediments are behaving most of the time as a sink for the phosphate thrown out of the factory and some times as a source emitting particles of phosphate into the water and contributing to the fertilizing process. This area is exhibiting a phosphate equilibrium state between the pelagic and the benthic zones which is broken from time to time according to the increasing or decreasing in the factory's operational rhythm of production. This also confirms what was shown long time ago by Balasubrahmanyam (1961) that the sediments may contain enough exchangeable phosphate to replace that in the water. This can occur during wavy and unstable marine conditions where

the shallow bottom is disturbed by different hydrodynamic processes. It can be assumed that orthophosphates measured in water may not have always the same origin (the factory) but they may rise from below (sediments).

Vertical distribution of phosphate and organic matters in sediments

In the area located far from the factory's outlets, most sediment levels showed low inorganic phosphate associated with weak organic matters concentrations with respect to the sediments of the area close to the factory. Inorganic phosphate did not follow a regular distribution and its evolution was not rhythmic while going through the sediment core. At certain stations, the concentrations decreased downwards and in others they increased. For example, phosphate concentrations increased gradually from M1 to M6, while approaching the outlet at the factory's south wall. But for each station, the sediment column showed homogeneous inorganic phosphate distribution with a small advantage at the deepest levels of both stations M5 and M6, while the vertical evolution of organic matters, that was normally supposed to decrease downwards, was homogeneously disturbed.

The stations located somehow far from the factory's outlets could be subjected to natural biodegradation of their organic matters contents through the sediment levels. The irregularity of organic compounds distribution in sediment core is due to the fact that in open and shallow water, the sea bottom is subjected to active hydrodynamism. It is well known that the vertical penetration into the sediments is accompanied by a decrease in organic matters concentrations (Laborde & Romano, 1983; Fichez, 1991; Fabiano & Danovaro, 1994). But in these stations, the vertical distribution reflected the mineralization of organic matters accompanied with continuous disturbance of the shallow sea bed by hydrodynamic processes such as waves and wind driven currents, seasonal activity of Al-Jaouz River, irregularity of the Selaata factory's operations and fishing boats movements through Batroun's port exit. These continuous water movements have created this homogeneity through the whole sediment column. The sediments are mixed and thus they were more or less homogeneous in the different cores of stations (M1 to M6), while the two stations M12 and M13 were somehow far from the plant's direct influence to reveal part of its chronological evolution. In this part of Batroun area, no evidence on the factory's operating history could be deduced. Here appears the difficulty to elaborate a chronological interpretation on the Selaata plant operations out of the first zone's data.

The stations of the second zone located under the direct influence of the factory's outflows were characterized by the extremely high concentrations of inorganic phosphate all along the sediment column compared to those of the first zone stations, especially if one considers the furthest station M13 as a control point, and also by a greater content of organic matters than the stations of the first zone where their distribution appeared to be rather homogeneous.

At station M7, the analysis of the sediment column showed that the deep levels were more than three times richer in inorganic phosphate than the upper ones with an increase in organic matters concentrations from surface till deepest level. The core was visually characterized by the presence of two layers clearly separated by the color's differences: an upper clear one and a bottom dark one. This change in phosphate content between the upper and the lower layers could only be explained by the change in the quantity and the quality of the thrown matters through time. Also, the higher content of organic matters in the deeper levels than the upper ones suggests that the sediment was subjected to reduction processes

which have inhibited the degradation of organic compounds (Laborde & Romano, 1983; Romano & Laborde, 1983). All these facts lead us to a clear conclusion that, at this station, the emissions have changed not only in quantity but also in quality where they became less toxic with time.

The situation is very different at station M8, where the concentrations of inorganic phosphate were almost the same all along the sediment column but they were lower than in the other stations. It is important to remember that the sediments at this station had a particular grain composition (99% of fine fraction) made especially of phosphogypsum. These lower concentrations in organic phosphate resulted from the fact that phosphogypsum doesn't release phosphate easily during analysis (Darmoul *et al.*, 1980). The concentrations of organic matters along the sediment levels were homogeneous, meaning that the biodegradation was restricted. This situation leads us to consider these outflows particularly of high toxicity. So differently from station M7, the emissions in front of station M8 did not change in composition or in flow intensities during time and the nature of emissions was always solid. It is interesting to mention that during two years of water sampling at these two stations (unpublished data), M7 and M8, there was no modification in water temperature, salinity and pH, and the water was usually clear with no stronger turbidity than at stations M9 and M10. In those latter stations the water was turbid and white which is an indication of strong rejection of phosphate and fine particles. On the contrary, at stations M7 and M8, some times it was noted the presence of brown turbid water which could be the pulp of phosphogypsum according to Darmoul *et al.* (1980) descriptions.

At station M9, located in front of the main west-northern outlet, the inorganic phosphate concentrations were extremely high and showed homogeneity through the whole sediment column associated with a great percentage of the fine fraction. On the other hand, the content of the organic fraction (CPL) decreased from surface towards the bottom end of the core. It can be assumed that at this station the emissions were continuous in quantity and quality and they were certainly less toxic since a clear tendency of organic matters degradation from bottom till surface could be observed. So the process of degradation was running normally, as if the medium was well oxygenated (Buscail *et al.*, 1995). The sediment core at station M10, located beside the jetty and 200 m to the north of the main west-northern outlet and where the percentage of fine fraction was low, showed a clear separation in inorganic phosphate concentrations between level (3-6 cm) and level (6-9 cm). The concentrations were higher in the upper levels than in the lower ones. In comparison with the other stations located close to the factory, this was the only one where one could notice higher concentrations in the surface than in the bottom. This could be explained by the fact that the jetty was built approximately 25 years ago, thus several years after the beginning of the factory's operations over 50 years ago, has objectively created a barrier. So the rejected materials from the west-northern outlet are carried towards the north with the general current (south to north), once confronted with the jetty, a zone of accumulation was established at M10 location. The observation of organic compounds evolution through sediment column showed that there was a rapid disappearance of the organic compounds going down through the core. At this zone of accumulation, the capacity to maintain sufficiently oxidizing conditions permitted the trapped organic materials to go through a reasonable degradation from the upper levels till complete vanishing at the bottom ones.

So, the vertical variation of the organic compounds associated with the inorganic phosphate distribution in the sediments of the stations subjected to the direct influence of the

factory allowed us to go partially through the chronological impact and operating mode of the Selaata chemical factory.

CONCLUSION

The variability of phosphate distribution in Batroun surface sediments has confirmed the separation of Batroun coastal area into two zones: the first one comprises the stations located somehow out of the main outlets' influence of Selaata factory (M1 to M6 and M12 to M13) and the second one contains the stations affected directly by the plant (M7 to M10). It has also shown that Selaata chemical plant was extending its influence far away from its main outlets and that a considerable part of Batroun marine area was subjected to variable degrees of phosphate contamination. As a matter of fact, this area could act, as a sink and as a source for phosphate.

As Selaata chemical plant was constructed more than 50 years without any information about its functioning schedule and system, the vertical distribution of phosphate in sediments associated with organic matters content has been fruitful to draw a preliminary map for the plant's operational history. It has shown that the sedimentation rate produced by Selaata factory dominates the hydrodynamic perturbation of the coastal area. This means that the plant's influence is dominant over the natural sedimentation processes.

This study shows that the studied part of Batroun marine area was subjected to continuous fertilization in phosphate and that the history of sedimentation due to the different active outlets can be read from the sediments of the north-western side of the plant.

This work may constitute the base to proceed with further studies on this subject by applying more reliable sampling strategies and by covering a larger area permitting us to detect the end limit of the plant's impact on sedimentary levels, vertically and horizontally.

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