Assessment of water quality by analyzing heavy metals in the Levrier Bay (Nouadhibou, Mauritania)

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ABSTRACT

In this study, variations in physicochemical parameters and heavy metal contamination in water of the Baie de Lévrier are instigated from 25 stations to assess the quality of water. The pH of the waters is relatively basic and the temperatures are a little high compared to the temperatures of the Atlantic Ocean in December. The measured conductivity remains within the range of known conductivity quantities that is 56 µS/cm for the oceans. The average concentration of the four heavy metals in water is therefore in the order of 0.02. The comparison with the background (SE26) allows us to note that: - concentrations of Cu are either low or similar to those of the stations SE5, SE8, SE10, SE12, SE13, SE24, SE25, - concentrations of Co are relatively high in most stations SE2, SE4, SE6, SE9, SE11, SE13, SE16, SE17, SE18, SE19, SE20, SE21, SE22, SE23, SE24, particularly in stations SE14 and SE16.; - As concentrations are the same excepted the station SE1; - concentrations of Mo in the stations SE4, SE6, SE9, SE12, SE14, SE21, SE23, SE24 are relatively higher compared to that of the background, while in the other stations the concentrations are low. Calculated pollution values (IPs) are less than 1, suggesting the absence of pollution in the analyzed water. Igeo values are all very low (Igeo<<0) and attest to a very low level of contamination, the enrichment factor (EF) displayslarge values (>1) for arsenic, particularly at stations SE1 (EF=70), SE5 and SE22 (EF=7). Such values would be related to the influence of external discrete sources like industrial activities and other anthropogenic origins.

Key words : Heavy metals, Pollution assessment, Water, Nouadhibou, Mauritania

Introduction

Industrial and maritime activities are sources of many environmental problems. The heavy metals resulting from these activities constitute a danger to public health when they manage to contaminate water (Armitage *et al.,* 2007; Khadse *et al.,* 2008; Venugopal *et al.,* 2009; Yuan *et al.,* 2011). Waters have been the subject of several studies with the aim of knowing the state of their pollution and the geochemical mechanisms which govern the migration of metals (Smith et Bradshaw, 1972; Merrington et Alloway, 1994; Fanfani *et al.,* 1997; Paquette *et al.,* 2000; Jung, 2001; Jabour, 2009).

In our case, we were interested in studying the distribution of metallic trace elements in the coastal waters of the Levrier Bay. The purpose of this study is to know the levels of metallic trace elements (ETM) in the waters of the Bay and their relationship with industrial activities and their discharges.

Twelve heavy metals (Pb, Zn, Ni, Co, Cr, V, Hg, Cu, Mo, As, Cd, Mn) were determined in the sampled waters as well as the usual ions (Cl⁻, Ca⁺⁺, Na⁺, K⁺, Mn⁺⁺, Mg⁺⁺, Fe⁺⁺, SO$_4^-$ and NO$_3^-$).

Methodology

Study area

The Levrier Bay is an area rich in industrial and fishing activities. It houses four ports around which are concentrated more than 60 industrial companies working in the fishing sector, mainly in the fishmeal and fish oil industry, in addition to the mines. The Levrier Bayis one of the most fish-rich areas in the world. From an ecological point of view, it encompasses two remarkable sites, the Cap Blanc satellite reserve and the Etoile Bay. This area is at the origin of the development of the city of Nouadhibou; economic capital and second largest city of Mauritania (Figure 1). Due to its contribution to socio-economic development (job creation, assessment of fishery products, etc.), industrial activity in the area is the source of several direct discharges of wastewater into the bay's waters and the surrounding soil. This could have a negative impact on the environment and public health. This work proposes to carry out an environmental assessment of the sediments of the Levrier Bay on the basis of eleven metallic trace elements (Pb, Zn, Ni, Co, Cr, V, Hg, Cu, Mo, As, Cd) and to study source (s) and the spatial distribution of the latter throughout this marine sediments area. This study can be considered the first attempt to evaluate the heavy metals pollution in marine sediments of Levrier Bay by using pollution load index, Enrichment factor and geoaccumulation index.

Sampling method

The first campaign was carried out during the winter season corresponding to the month of December 2019. The geographical position of the sampled points was determined using a GPS, but also using the existing geographic and geological cartography. Sampling points are referenced by a letter and a number.

The experimental study was carried out on marine waters from the coast of the Levrier Bay. Sampling was done systematically. Water was sampled at a set of points covering the entire study area along the coastline between Cap Blanc and the Etoile Bay, around the town of Nouadhibou and on the other side of the Greyhound bay (Figure 2). 25 points were sampled in addition to a control point far from any industrial activity.

Geochemical processing

In order to know the concentration levels and assess the risk of contamination of the waters of the Bay by these metals, geochemical analyzes of the waters were carried out for the following chemical elements: Pb, Zn, Ni, Co, Cr, V, Hg, Cu, Mo, As, Mn and Cd.

The water samples taken were stored in polyethylene bottles intended for the various analyzes and after the addition of 4% nitric acid. The temperature, pH and electrical conductivity parameters of the waters were measured in situ.

Analyzes of metallic trace elements (Pb, Zn, Ni, Co, Cr, V, Hg, Cu, Mo, As, Mn, Cd), analyzes of major elements (Ca, Mg, K, Na, P, S, N, C; Si and Al) were carried out by ICP-MS (Analysis by mass spectrometry coupled to an inductive plasma) at the ALS
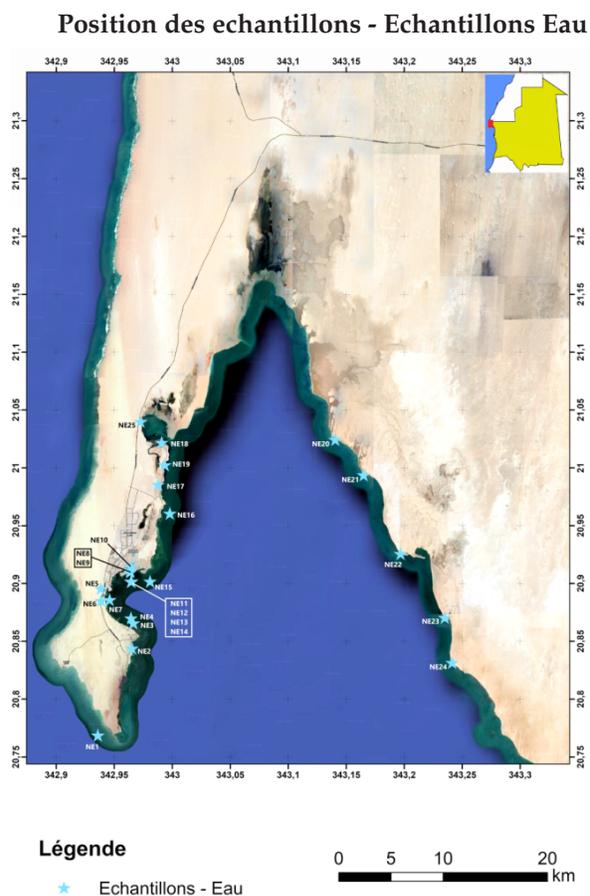

Position des echantillons - Echantillons Eau

Fig. 1. Map of water sampling points

S434

Eco. Env. & Cons. 28 (October Suppl. Issue) : 2022

Laboratory in Dublin (Ireland).

The analytical method used to evaluate the marine waters geochemistry is the super Trace Lowest DL AR by ICP-MS. The Super Trace method combines an Aqua Regia digestion with ICP-MS instrumentation utilizing collision/reaction cell technologies to provide ultra-low detection limits. Instrumentation has been optimized for long-term ICP-MS signal stability, in particular for samples with high Ca content. The extremely low detection limits are particularly useful for exploration in waters, and the methods can also be performed on the clay fraction of soils (Clay size fraction separation is available using ALS method SCR-CLAY.) This method is not appropriate for mineralized samples. ME-MS41L: For the ALS standard Aqua Regia digestion a prepared sample (nominal 0.5g) is digested with 75% Aqua Regia (3:1 ratio of HCl:HNO$_3$) in a graphite heating block.

Results and Discussion

Physic-chemical parameters

Temperatures: The temperature fluctuates between 16.86 and 23.66 °C. The background St27 has a temperature of 17.17 °C. These temperatures are a little high compared to the temperatures of the Atlantic Ocean in December (cabaigne.net).

pH

The physico-chemical study carried out in our sector showed that the pH values vary between 7.6 and 8.83 (Figure 2) which corresponds to basic water, the background presents water with a slightly basic pH of 7.4 (Item St27).

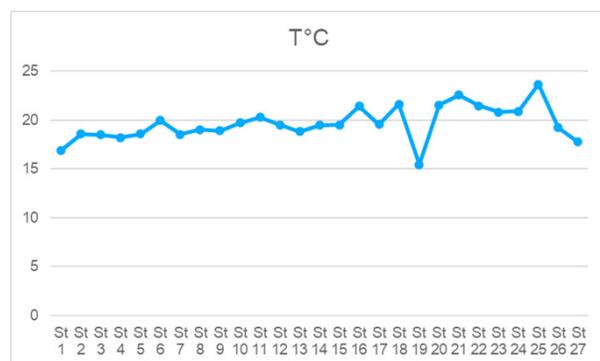However, it should be noted that the pH varies naturally during the year (Encyclopædia

Universalis). In fact, it passes through a maximum in spring, when phytoplankton grows, i.e. when photosynthesis (with consumption of dissolved CO2) is active, and through a minimum in autumn, when the production of CO2 by biodegradation organic matter predominates. This seasonal difference varies from 0.030 to 0.070, which is much more than the annual trend due to the enrichment of the ocean in atmospheric CO2 of anthropogenic origin. To distinguish, in the variation measured, the part due to human activities from that corresponding to a natural seasonal variation, it is necessary to have very precise measurements accurate pH and long-term series. We also see that if the pH drops, it always remains above 7 (neutrality), which characterizes a basic solution.

Electrical conductivity: The conductivity of water depends on the geological nature of the crossed rocks (Petelet *et al.,* 1998).

The electrical conductivity oscillates between 53.01 and 60 mS/cm (Figure 3). The background (St27) has a conductivity of 66.95 mS/cm higher than that of Baie du Lévrier. The conductivity is in the range of known conductivity quantities which is 56 µS/cm for the oceans
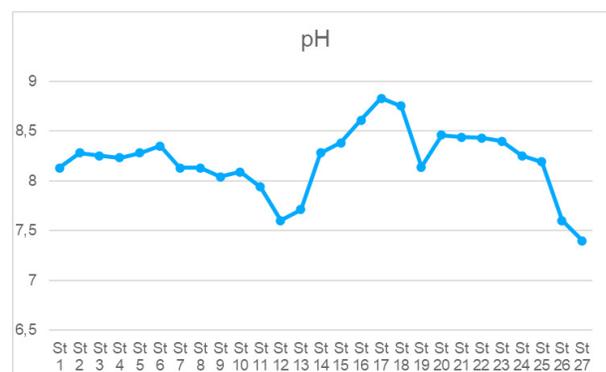

Fig. 3. Evolution of water pH per sampling point

Major elements

The content of major elements in the waters of Levrier Bay differs from one station to another (Table 1). For the hardness parameters, iron and manganese have average concentrations of 5.75 and 7.6 mg/l respectively. These elements therefore have levels higher than potability standards (European, 1991; Moroccan standards, 2002; Table 1.). Chlorine, calcium, sodium, magnesium and potassium have normal levels according to Moroccan recommendations (N. M., 2002) on drinking water
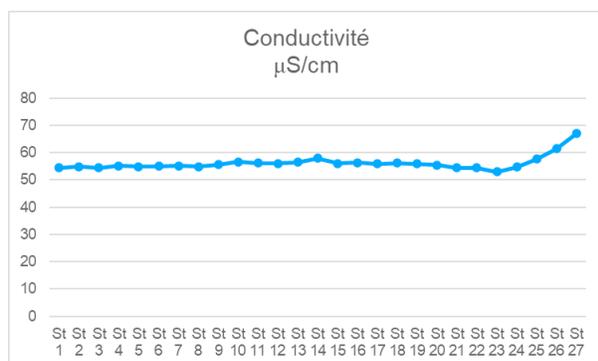

Fig. 2. Evolution of water temperature per sampling point

Fig. 4. Evolution of water electrical conductivity per sampling point

(Table 1). The waters of the area are bicarbonate-calcic.

Metallic pollution of the waters of the levrier Bay

The concentrations of four analyzed elements (Cu, Co, As, Mo) are given in Table 2. The other elements are not presented here since their concentrations are not detected (<0.001mg/l). The Cu content varies between 0.02 and 0.03 with an average value of 0.02. The Co content varies between 0.01 and 0.03 with an average value of 0.02. The As content varies between 0.012 and 0.7 with an average value of 0.02. The Mo content varies between 0.01 and 0.02 with an average value of 0.01.

The average concentration of the four heavy metals is therefore in the order of 0.02. The four elements also have very low median values (0.02). The comparison with the composition of the background(SE26) allows us to note the following remarks (Figure 5):

- the concentrations of Cu are almost similar in the stations SE5, SE8, SE10, SE12, SE13, SE24, SE25, while in the other stations the concentrations are low;

- the concentrations of Co are relatively high in stations SE2, SE4, SE6, SE, 9, SE11, SE13, SE16, SE17, SE18, SE19, SE20, SE21, SE22, SE23, SE24, particularly in stations SE14 and SE16. While in the other stations the concentrations are almost the same;

- the As concentrations are particularly higher in the station SE1, while in the other stations the concentrations are the same;

Table 2. Metal contents measured by sampling station

Sample	Cu mg/l	Co mg/l	As mg/l	Mo mg/l
SE1	0,02	0,01	0,7	0,01
SE2	0,02	0,02	0,04	0,01
SE3	0,02	0,01	0,03	0,01
SE4	0,02	0,03	0,01	0,02
SE5	0,03	0,01	0,06	0,01
SE6	0,02	0,02	0,01	0,02
SE7	0,02	0,01	0,05	0,01
SE8	0,03	0,01	0,04	0,01
SE9	0,02	0,02	0,01	0,02
SE10	0,03	0,01	0,01	0,01
SE11	0,02	0,02	0,05	0,01
SE12	0,03	0,01	0,03	0,01
SE13	0,03	0,02	0,02	0,01
SE14	0,02	0,01	0,01	0,02
SE15	0,02	0,01	0,01	0,01
SE16	0,02	0,03	0,01	0,01
SE17	0,02	0,02	0,01	0,02
SE18	0,02	0,02	0,01	0,01
SE19	0,02	0,02	0,01	0,01
SE20	0,02	0,02	0,04	0,01
SE21	0,02	0,02	0,02	0,02
SE22	0,02	0,02	0,07	0,01
SE23	0,02	0,02	0,02	0,02
SE24	0,03	0,02	0,01	0,02
SE25	0,03	0,01	0,02	0,01
Standard OMS	2	0,02	0,01	0,07
Mean	0,02	0,02	0,02	0,01
Min	0,02	0,01	0,01	0,01
Max	0,03	0,03	0,7	0,02
Median	0,02	0,02	0,02	0,01
SD	0,069	0,080	0,097	0,005
VC	1,04	0,35	4,86	0,82
Quart 1	0,02	0,01	0,01	0,01
Quart 3	0,03	0,02	0,04	0,02
PI Mean	0,29	2,55	0,82	0,12
PI Min	0,25	1,00	0,09	0,05
PI Max	0,38	22,70	8,91	1,45

Table 1.Physico-chemical parameters of waters
* Normes (N. M., 2002)

Element (mg/l)	Cl	Mn	Ca	Na	Mg	K	Fe	SO4	NO3
Minimum	2,56	0,004	11.82	30.25	17.68	2.9	0,1	95,5	0,83
Mean	98,56	0,04	49.5	96.28	43.27	7.83	0,55	187	20,14
Maximum	535	0,14	98.14	215.99	74.91	11.6	2	356	70,82
Standard*	200	5	100	150	50	12	1 - 2	250	50

S436

Eco. Env. & Cons. 28 (October Suppl. Issue) : 2022

- the concentrations of Mo in the stations SE4, SE6, SE9, SE12, SE14, SE21, SE23, SE24 are relatively higher compared to that of the control sample, while in the other stations the concentrations are low. Comparison with OMS values allows to notify that only the As element is higher (Table 2).

The calculation of the average of the PIs pollution indices compared to the respective heavy metal values of the background SE26 (Table 3) shows low values for all the analyzed elements (Cu, Co, As, Mo). All IPs values are less than 1, except Cu with a value of 2.55. This leads to the conclusion that there
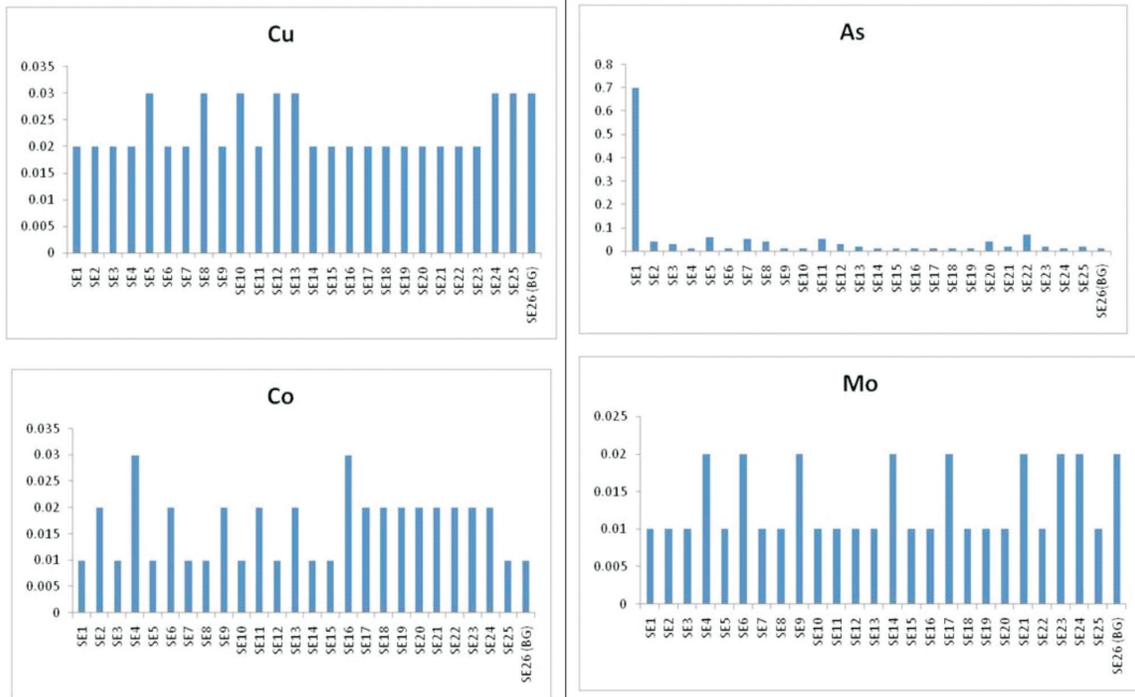
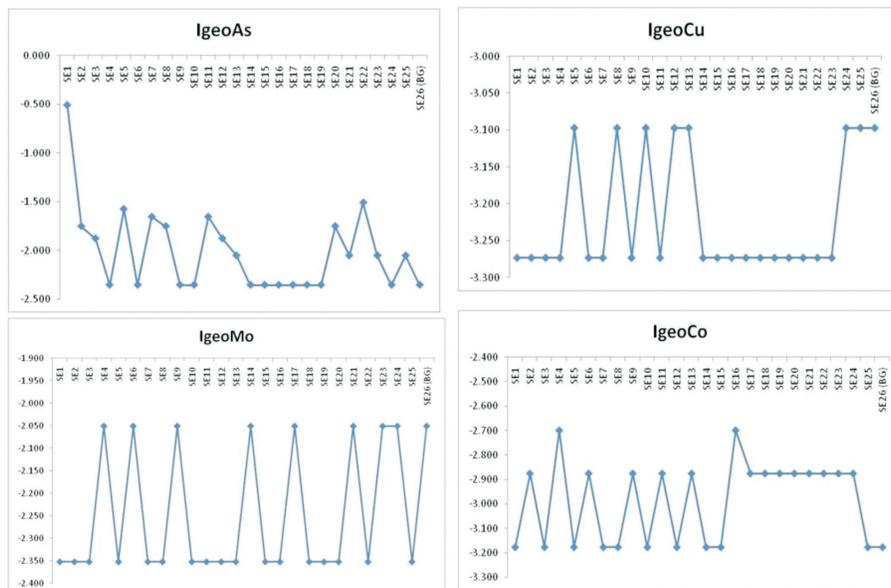**Fig. 5.** Comparison of metal contents measured by sampling station

Fig. 6. Comparison of the values of four heavy metals measured by sampling station

is no pollution of the analyzed water.

- Co concentrations are relatively high in the majority of stations.

The geo-accumulation index is a quantitative measure of the degree of pollution in aquatic waters and sediments (Muller, 1979). It consists of seven grades ranging from unpolluted to very extremely polluted.

Table 3 presents the geo-accumulation index for the quantification of the accumulation of heavy metals in water samples taken from different stations. Igeo values vary very slightly from one metal to another. However, the different values obtained for the four metals and in all the stations are all very low (Igeo<<0) and make it possible to classify the water samples from the study area as having a very low level of contamination, indicating that the anthropo-

genic impact in the studied marine waters is insignificant (Figure 6 and 7).

The enrichment factor (EF) is calculated to assess the importance of the enrichment and/or depletion of heavy metals in the sea water of the "Baie de Lévrier" (Table 4). The results of the present study show that the EF values of the metals analyzed are variable (Figure 7). For Cu and Mo, the values are less than or rarely equal to 1. For Co, in most stations, the values are between 1 and 3. Large values of EF (>1) are recorded for arsenic, particularly in stations SE1 (EF=70), SE5 and SE22 (EF=7). These high values would be related to the influence of discrete external sources such as industrial activities and other anthropogenic origins.

The heavy metal concentrations are normalized to the background (SE26).

The results in Figure 7 confirm this finding and show that arsenic remains the most abundant metal in water, especially in sample SE1.

Table 3. Classes of the geo-accumulation index (Igeo) in the studied samples

Sample	IgeoCu	IgeoCo	IgeoAs	IgeoMo
SE1	-3,273	-3,176	-0,507	-2,352
SE2	-3,273	-2,875	-1,750	-2,352
SE3	-3,273	-3,176	-1,875	-2,352
SE4	-3,273	-2,699	-2,352	-2,051
SE5	-3,097	-3,176	-1,574	-2,352
SE6	-3,273	-2,875	-2,352	-2,051
SE7	-3,273	-3,176	-1,653	-2,352
SE8	-3,097	-3,176	-1,750	-2,352
SE9	-3,273	-2,875	-2,352	-2,051
SE10	-3,097	-3,176	-2,352	-2,352
SE11	-3,273	-2,875	-1,653	-2,352
SE12	-3,097	-3,176	-1,875	-2,352
SE13	-3,097	-2,875	-2,051	-2,352
SE14	-3,273	-3,176	-2,352	-2,051
SE15	-3,273	-3,176	-2,352	-2,352
SE16	-3,273	-2,699	-2,352	-2,352
SE17	-3,273	-2,875	-2,352	-2,051
SE18	-3,273	-2,875	-2,352	-2,352
SE19	-3,273	-2,875	-2,352	-2,352
SE20	-3,273	-2,875	-1,750	-2,352
SE21	-3,273	-2,875	-2,051	-2,051
SE22	-3,273	-2,875	-1,507	-2,352
SE23	-3,273	-2,875	-2,051	-2,051
SE24	-3,097	-2,875	-2,352	-2,051
SE25	-3,097	-3,176	-2,051	-2,352
SE26 (BG)	-3,097	-3,176	-2,352	-2,051
Median	-3,273	-2,875	-2,051	-2,352
Max	-3,097	-2,699	-0,507	-2,051
Min	-3,273	-3,176	-2,352	-2,352
Quartile 1	-3,273	-3,176	-2,352	-2,352
Quartile 3	-3,097	-2,875	-1,750	-2,051

Table 4. Enrichment Factor (EF) classes in the studied samples

Sample	EFCu	EFCo	EFAs	EFMo
SE1	0.67	1	70	0.5
SE2	0.67	2	4	0.5
SE3	0.67	1	3	0.5
SE4	0.67	3	1	1
SE5	1.00	1	6	0.5
SE6	0.67	2	1	1
SE7	0.67	1	5	0.5
SE8	1.00	1	4	0.5
SE9	0.67	2	1	1
SE10	1.00	1	1	0.5
SE11	0.67	2	5	0.5
SE12	1.00	1	3	0.5
SE13	1.00	2	2	0.5
SE14	0.67	1	1	1
SE15	0.67	1	1	0.5
SE16	0.67	3	1	0.5
SE17	0.67	2	1	1
SE18	0.67	2	1	0.5
SE19	0.67	2	1	0.5
SE20	0.67	2	4	0.5
SE21	0.67	2	2	1
SE22	0.67	2	7	0.5
SE23	0.67	2	2	1
SE24	1.00	2	1	1
SE25	1.00	1	2	0.5
SE26 (BG)	1.00	1	1	1

S438

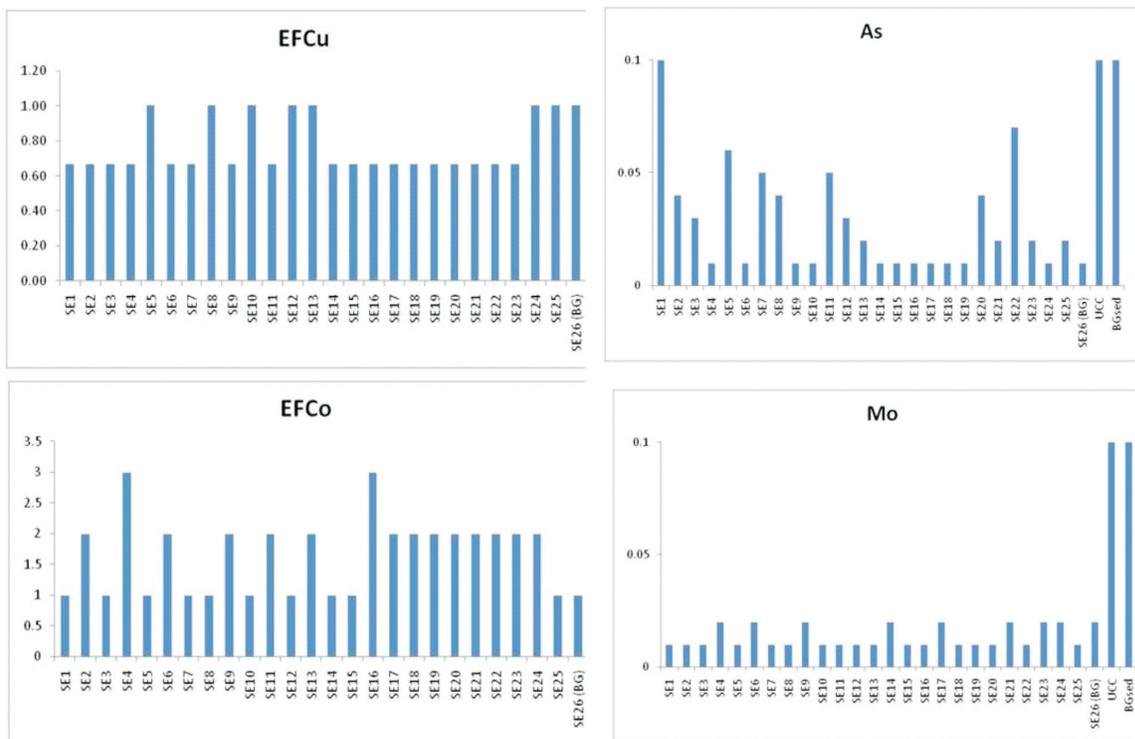*Eco. Env. & Cons. 28 (October Suppl. Issue) : 2022*

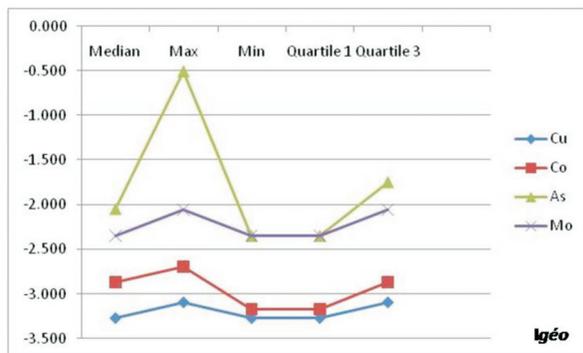**Fig. 7a.** Statistical distribution of Igeo in the four stations

Fig. 7b. Enrichment index values by sampling station

Conclusion

This study made it possible to assess the pollution in the waters of the Bay of Levrier, based on certain pollution indicators such as the physico-chemical parameters: temperature, pH, electrical conductivity and metallic trace elements (Cu, As, Mo and Co). On each of the 25 stations studied, the measured values show more or less significant fluctuations. The pH of the waters is relatively basic and the temperatures are a little high compared to the temperatures of the Atlantic Ocean in December. The measured conduc-

tivity remains within the range of known conductivity quantities that is 56 μS/cm for the oceans.

All the calculated pollution values (IPs) are less than 1, which suggests the absence of pollution of the analyzed water. Cu with a value of 2.55 is the exception. However, the different Igeo values obtained for the four metals and in all the stations are all very low (Igeo<<0) and attest to a very low level of contamination, indicating that the anthropogenic impact in the marine waters studied is insignificant.

The enrichment factor (EF) in the present study shows variable values. They are less than or rarely equal to 1 for Cu and Mo, low for Co, (between 1 and 3). Large values of EF (>1) are recorded for arsenic, particularly at stations SE1 (EF=70), SE5 and SE22 (EF=7). These high values would be related to the influence of external discrete sources such as industrial activities and other anthropogenic origins.

The concentrations of heavy metals, normalized to the background (SE26), show that arsenic remains the most abundant metal in the water, especially in the SE1 sample.

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