



METALLIC POLLUTION AFFECTING THE BAY OF TANGIER AND ITS CONTINENTAL EMISSARIES: ANTHROPIC IMPACT

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ABSTRACT

Geochemical study of superficial sediments of Tangier bay and its continental emissaries was carried out with the aim of evaluating the contamination degree of the sediments by heavy metals and their impact on the coastal marine environment. In Tangier bay, two sectors are distinguished: the Eastern one, with prevalence of sandy facies, and the western sector characterized by fine sediments and rich in organic carbon. The carbonates are localized to offshore of the bay. In the continental emissaries, the granulometric facies distribution shows an increasing grain evolution from downstream to upstream. The carbonates and organic carbon show a slightly increasing enrichment from the upstream to the downstream of the emissary. The results of the geochemical analyses show that the high contents of heavy metals are located in the western sector of the bay, in front of the Souani and Mghogha rivers mouths and on the downstream part of the continental emissaries. The high variations of the metals contents reveal the existence of anthropogenic

origin pollution, in direct relation with the domestic and industrial liquid and solid discharges. The results of the statistical data show in the bay the presence of heavy metal association constituted by Pb>Zn>Cu>Cd>Ni, while in the continental emissaries, the dominant association is represented by Pb>Cu>Sable>Ni>Cr. These two metallic associations testify an increasing gradient of sediments pollution and the anthropic degree of the studied zone. On the socio-economic level, these data will contribute to a better management of the protection of coastal marine environment as well as the economic and tourist development of the Tangier region.

INTRODUCTION

At present, on a world level we attend an expansion and an increase of the industrial and agricultural activities as well as an accelerated growth of the population. The discharges (industrial and domestic) of the human activities sometimes untreated are transported by means of the continent streams towards the marine environment. This last constitutes the ultimate seat of the accumulation of these products, which before their arrival in the ocean; they can pass in transit or accumulate in the protected coastal marine environments as the bays and the lagoons. The pollution of these environments by heavy metals and

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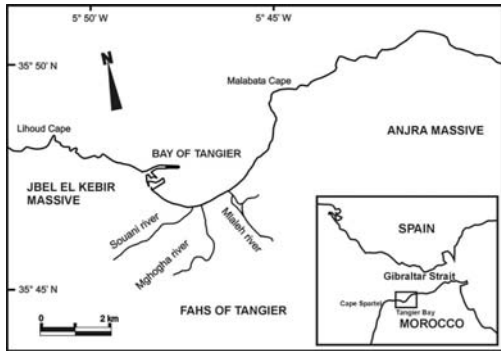


Figure 1:
Geographical situation of the study area

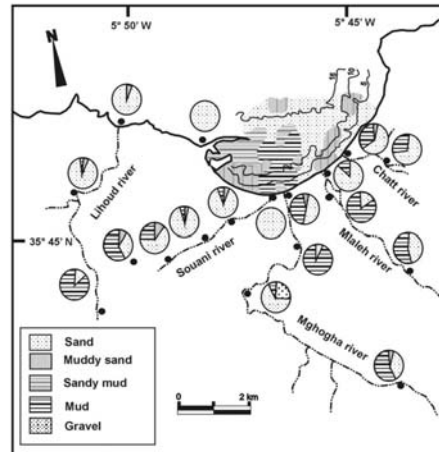


Figure 3:
Sedimentary facies distribution in the study area

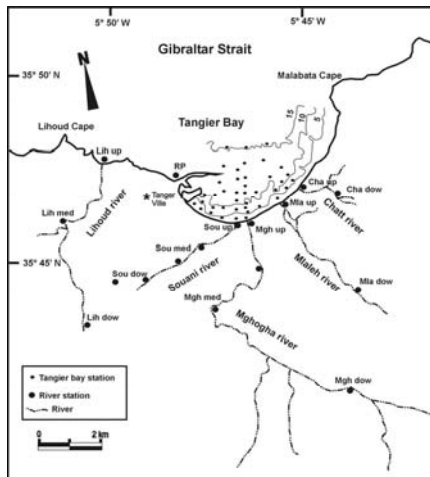


Figure 2:
Location of the sampling stations
RP: Largest pipeline, Lih up: Lihoud upstream, Lih med: Lihoud median, Lih dow: Lihoud downstream, Sou: Souani, Mgh: Mghogha, Mla: Mlalet, Cha: Chatt

other chemicals products can have fatal repercussions on the marine environment, but also the long-term effects on the human health (Boucheseiche *et al.*, 2002). Therefore, the consumption of contaminated seafood can also constitute a potential sanitary risk (WHO/UNEP, 1995; Saux *et al.*, 2003). The organic matter in excess in the confined marine systems constitutes a source of pollution which generates some dysfunctions in the trophic chain (Gold, 2002).

The bay of Tangier constitutes one of the coastal zones of Morocco, which knows an urban pressure encouraged by an industrial and tourist activity. Its marine domain is particularly vulnerable to any sort of pollution (organic and inorganic) which takes various aspects whose certain forms are very dangerous, leading to cases of not easily reversible degradations. These activities led to the increase of the anthropic origin pollution affecting the coastal marine environment of the bay and its continental emissaries. This pollution is directly related to the rejection of the domestic and industrial effluents which arrive directly on beaches by natural outlets system (rivers) or by the discharges.

The geochemical studies of the sea water samples and surface sediments of Tangier bay and its continental emissaries, were the object of numerous recent works, mainly by El Arrim (2001, 2002 & 2003), El Hatimi (2002 & 2003), Amendis (2003 & 2005), Sabhi *et al.* (2000), Armoured (2000), Dahhou (1999), Agoumi (1998) & the RAID (1994) among others. Similar works was realized on the Moroccan Mediterranean margin (El Moumni *et al.*, 1992; El Moumni *et al.*, 1999), in the lagoon of Nador-Morocco (Inani, 1995; El Alami *et al.*, 1998; Mahjoubi, 2001, Bloundi, 2002; Bellucci *et al.*, 2003), in the Moulouya river-Morocco (Foutlane, 1983), in bay of Algiers (Maouch, 1987) and in Sebkhha of Ariana-Tunisia (Bloundi, 2001). Other recent works were led on the

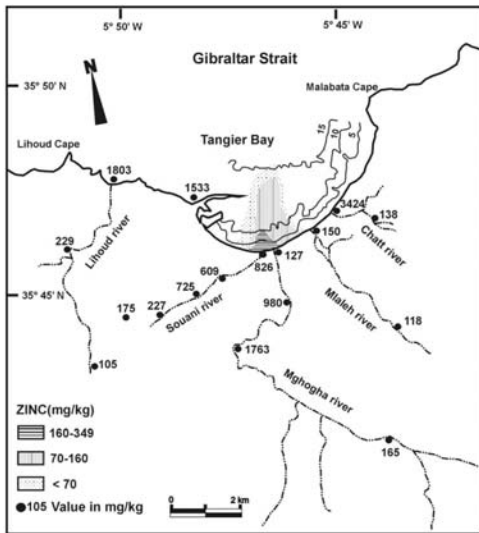


Figure 7:
Distribution map of the Zinc contents

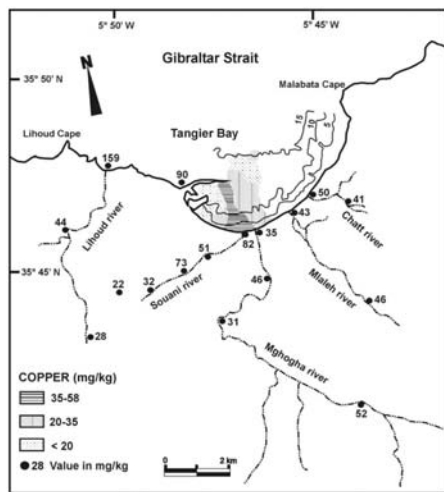


Figure 8:
Distribution map of the Copper contents

crossing from south toward the north the urbanized and industrialized zones of Tangier city. These rivers by order of hydrological and hydraulic importance are (Fig.2): Mghogha river, Souani river, Lihoud river, Mlaleh river and Chatt river. The annual solid output rate of all the Rivers discharging in the bay is estimated between 60 000 and 70 000 t/an, from which

70 % result from the Mghogha river (L.C.H.F. 1974). The solid contributions are mainly of fine elements consisted by silts and clays which settle beyond bottoms of -3 m, between the port and the mouth of the Mghogha river. In the eastern zone of Tangier bay, the fluvial contributions of sand, gravels and pebbles are estimated from 5000 to 10000 m³ (L.C.H.F. 1972 & Long, 1998).

From hydrodynamic point of view, the surge essentially comes from two sectors: NW and NE. The waves of West and NW sector come from the Atlantic and prevail to the offshore of the bay, with significant heights of 1.5 to 2.5m and periods of observations of 9 to 12 sec. After refraction, the surges of NW direction reach the bay perpendicularly to the coast; the diffraction of these surges creates a side current responsible for the transport of the sediments towards the west of the bay (L.C.H.F. 1974; El Bouzidi *et al.*, 2004)). The waves of East and NE sector are due to local winds sea, characterized by short periods of 3 to 5 sec, and heights inferior to 1.5m. These surges attack the east coastline of the bay with an impact of 20 to 30°, generating a coastal drift from East toward the West. Tide is of the semi-diurnal type with an average amplitude of 1.8 m. The tidal range of spring tides is 2.2 m and that of the neap tides is 0.8 m. The tidal current velocity oscillate between 1.8 to 2.7 m/s generated by the ebb, oriented towards the West, and that generated by the flow currents reach 2 m/s oriented towards the East (L.C.H.F. 1974 & Long, 1998).

MATERIALS AND METHODS

In Tangier bay, the sampling of surface sediments was carried out in two oceanographic cruises (July and October 1999) on board the N/O "ELDA", using a Shipek drag (El Arrim, 2001). A total of 41 sediment samples were carried out according to radial oriented N-S (Fig.2). The sample position was determined by Global Position System (DGPS). Another 17 sediment samples have been also extracted in May 2001 (Fig.2), using a hand bucket, along different emissaries (rivers) discharging in the bay (El Hatimi, 2003).

The grain size analysis consisted on the humid separation of coarse and fine fractions using a sieve of 0.063mm. The coarser material (>63µm) was dry-

sieved during 15 minutes. The determination of carbonates has been accomplished on bulk fraction by volumetric valuation, and the organic carbon was carried out on the fine fraction using a LECO-CN 2000 equipment.

The contents of heavy metals (Cr, Cu, Pb, Zn, Ni, and Cd) in the sediments were determined by Atomic Absorption Spectroscopy (AAS) equipment and by Inductivity Coupled Plasma (ICP-MS (model Perkin Flora Elan 6000)). The obtained results are expressed in mg/kg. In this work, the choice of these metals takes in consideration those most dangerous and most frequently met in the bay and its continental emissaries. Moreover these metals are usually used in the industrial units located in the river basins slopes of the study zone. The statistical processing of data was carried out using STATGRAPHICS Plus software. The Multivariate Factor analysis (AFM) was applied to geochemical and granulometric data obtained by analyses.

RESULTS AND DISCUSSION

Sedimentary facies

The distribution of superficial sediments in Tangier bay shows the presence of two main sectors, characterized by their sedimentological behavior and the dominant hydrodynamic regime (Fig.3). The oriental (eastern) sector shows the predominance of sandy facies, with decreasing gradient toward the West, sometimes present until depths of 15m. This sector is affected by the influence of surge, mainly waves coming from NE of the bay, responsible of the presence and predominance of sandy bottoms, indicating therefore an average to a high hydrodynamic regime (Achab *et al.*, 2005). The occidental (western) sector, generally protected of the NW surge is characterized by fine sediments of muddy nature, localized in front of the mouth of Souani and Mghogha Rivers reaching until 10 m of depth. In the protection zone of Tangier port, exactly in the extreme West of the bay, mixtures facies of muddy sand and sandy mud nature are present, indicating zone of low hydrodynamic regime (Achab *et al.*, 2005). Generally, the distribution of sediments in Tangier bay bottoms was found to be controlled by hydrodynamic factors, especially the surges of NE and NW direction as well

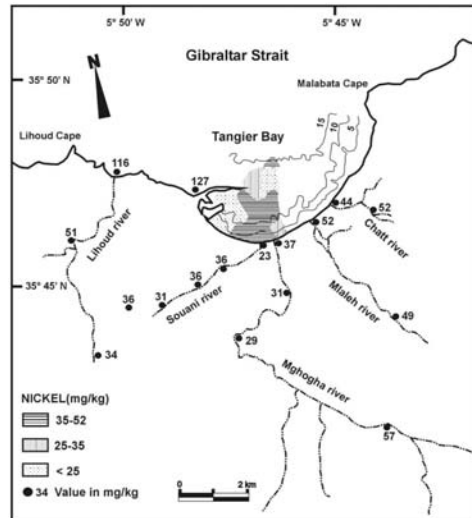


Figure 9: Distribution map of the Nickel contents

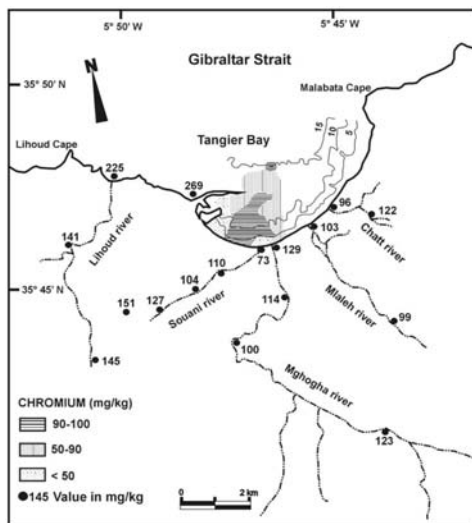


Figure 10: Distribution map of the Chromium contents

as by the main sources of supplies to the bay in particular the Souani and Mghogha Rivers.

The carbonates contents generally range between 12 % and 21 %. The high values (18-21%) are localized off-shore the bay, probably in relation to the abundance of the coarse facies of sandy nature rich in remains of shells (bioconstrictions) and other

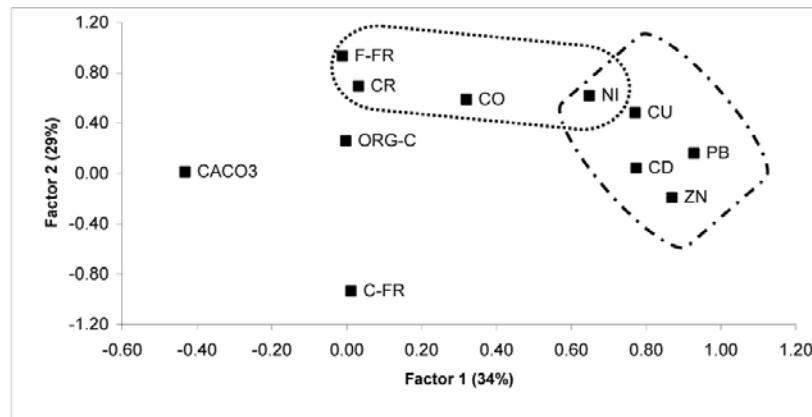


Figure 11: Binary diagram of F1 and F2 factors obtained for the bay of Tangier from the Multivariate Factorial Analysis. (C-Fr: coarse fraction, F-Fr: fine fraction, CaCo3: carbonate, Org-C: organic carbon)

carbonated components present offshore (fig.4). Similar results were found in other study zones as the case of Algiers (Maouch, 1987) and in the Eastern part of the Moroccan Mediterranean margin (El Mounni & Monaco, 1992). The contents in carbonates decrease slightly when we move away from the offshore. They are about 15 % on the central part of the bay with prevalence of mixed facies and lower than 12 % in the littoral zones located between isobaths of 5m and 10m, which generally coincide with fine facies of muddy nature. These low values of carbonate would be related to a local dilution by fluvial contributions of the principal rivers discharging in the bay (El Arrim, 2003).

Concerning the continental emissaries of Tangier Bay, the distribution of superficial sediments show the presence of coarser facies to the downstream and more fine to the upstream (Fig.3).The sands predominate all the studied stations; and characterize the downstream and median stations of Souani, Mghogha and Lihoud rivers. The mud generally prevails the upstream part, and the gravel appears only in the central part of the Mghogha river. The grain size distribution shows a decreasing evolution from downstream to upstream which results in a bad-sorted sediments and a poly-modal character. This seems to be different from the classic evolution, generally found in rivers, probably related with solid contributions; due to different industrial activities installed along the studied continental emissaries (artificial filling of river basins

by construction materials, among other). (El Hatimi *et al*, 2002).

The contents in carbonates are included between 7 % and 53 %. The highest concentrations appear along the stations of Souani river (53 %) While the weakest are found in the Lihoud River (7 % 13 %) characterized by the prevalence of quartzous sands, poor in bioclastes (Fig.4). The distribution of carbonates show generally an increasing upstream-downstream evolution (except Lihoud river), this variation reflect the nature of the formations crossed by these rivers (calcareous marls, argillocalcareous flysch, quartzous sands, etc).

Organic carbon

The concentrations of organic carbon in Tangier bay vary between 0.15 % and 0.84 %. These contents are generally lower than those found in the continental emissary (0.4 % to 31 %), this, is due probably to the effect of marine dynamics (capacity of self-purification of the bay water). The high values are concentrated in the Western part of the bay, characterised by the predominance of muddy sediments, while decreasing slightly towards the East and offshore of the bay (Fig.5).

In the continental emissaries, the percentages of organic carbon vary from a station to another one with average proportions of 4 % which can reach locally

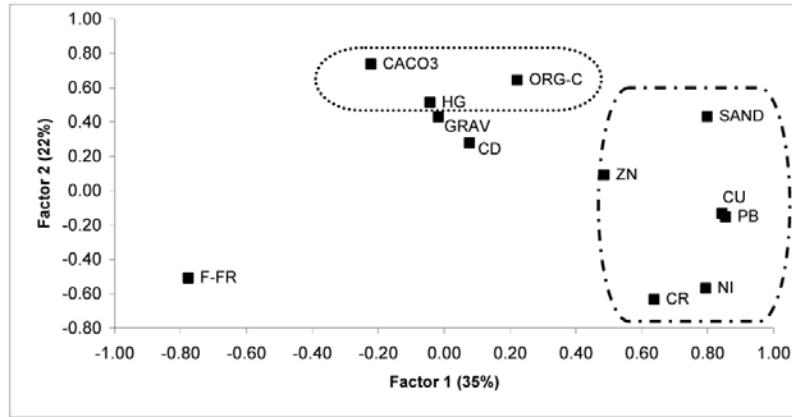


Figure 12: Binary diagram of F1 and F2 factors obtained for the continental emissaries from the Multivariate Factorial Analysis. (Grav: gravel, F-Fr: fine fraction, CaCo3: carbonate, Org-C: organic carbon)

until 31 % (Fig.5). The distribution of organic carbon contents shows that high values are concentrated in the central part and the downstream of the Souani river, place of accumulation of domestic and industrial wastewaters discharge. These high values are also present locally in the central part of Mghogha river who is near to the slaughter-houses (El hatimi *et al.*, 2002). The minima values are localised to the source of the principal rivers, in particular the Souani, Mghogha and Mlaleh rivers, which are practically remotely from organic load usually rejected by the urban and industrial activities. Generally, the organic carbon concentrations show a slightly increasing enrichment from upstream to downstream of rivers. The low contents found in the Mghogha and Chatt mouths (0.4 to 0.9 %) are due to the marine dynamics which makes dilute and decrease the concentration of the organic matter in the sediments.

Heavy metals

Heavy metals are among the principal polluting agents of the marine environment. The more part of them are generally associated to the suspended matter or to the sediments, in particular those of the surface layer because it is where the phenomena of adsorption are most active. They could have two possible origins: natural origin by partial degradation of the rocks and by washing of mining grounds or an industrial origin related to the human activity (Chabert, 1980 & Faguet, 1982).

Bay of Tangier: the results of heavy metals analyses of the superficial sediments show that the metallic elements have average values lower than those met in the continental emissaries pouring in the bay (Table 1).

-Lead (Pb): is very common in the nature, its concentration in the earth's crust is about 8 to 20 mg/kg (Levesque L, 1976). The principal sources of production of lead are the foundries and the mining industry. The industrial products responsible for the contamination of the marine environment by this element are the insecticides, the manures, the accumulator batteries, the industries of plastic, glassmaking, crystal manufacture and the ceramics.

The Lead contents in the superficial sediments of the bay vary between 8 and 82 mg/Kg (Table 1), the highest concentrations are located in the immediate vicinity of the Souani river mouth between isobaths 4 and 5 m. The average contents of this metal element are located between isobaths 5 and 10 m, then, decrease quickly towards the offshore (fig. 6).

Zinc (Zn): is a widespread metal in the earth globe, the average contents of zinc in the lithosphere is 1 mg/kg (Levesque, 1978). Zinc is largely used since numerous years in the industry (constructions, cars, manufacture of plunder, rubber, etc), which implies an important emission of this last to the environment.

Table 1:
Comparison of heavy metals concentrations in the superficial sediments of Tangier bay and its continental emissaries.

Heavy meals (mg/kg)	Lead (Pb)	Zinc (Zn)	Cooper (Cu)	Chromium (Cr)	Nickel (Ni)
Tangier bay	8-82	14-348	9-58	33-110	14-52
Emissaries (rivers)	16-610	105-3424	22-159	73-269	23-127

Zinc presents in the bay of Tangier the same diagram of distribution as the lead, with high concentrations at mouths of the Souani (348 mg/Kg) and Mghogha (170 mg/Kg) rivers. The Zinc contents decrease northwards until depths of 15m, then, decrease quickly in direction of the east and the west (fig. 7).

- Copper (Cu): copper is largely widespread in the nature, its concentration in the soils is about 20µg/g, whereas in the sediments, high concentrations (from 2 to 2000 µg/g) are frequent (Levesque, 1979). The principal transmitting sources of this metal are the mines, the fertilizing products and the domestic and industrial wastes coming primarily from the industry of textiles, paintings products, the cables and electric appliance (Levesque, 1979).

The concentrations of Copper in the bay range between 9 and 58 mg/Kg (Table 1). The distribution of this metal, shows that the high relatively concentrations are localised between the mouths of Souani (58 mg/kg) and Mghogha (32 mg/kg) rivers and at the north curved dam of Tangier port (48 mg/kg). These concentrations are configured in form of perpendicular band to the coast and the isobaths (fig. 8). The contents of copper decrease gradually towards the broad, but also to the east and the west direction of the bay.

- Nickel (Ni): is a not very abundant metal. In the uncontaminated areas, the nickel concentrations in the aquatic sediments are 2 to 20 µg/g (Levesque L. 1979). The principal anthropic sources of nickel come from the ore processing of nickel, from the treatment of the metallic surfaces scouring and the incineration of the waste industrial.

The concentrations of Nickel in the superficial sediments of the bay of Tangier range between 14 and 52 mg/Kg (Table 1). The distribution map of this metal shows that the high concentrations (35 and 52 mg/kg) are occupying the Western part of bay located between

the mouths of the Souani and Mghogha rivers (Fig.9). The weak contents of Nickel are located mainly at the West extremity of the bay.

- Chromium (Cr): its concentrations range between 33 and 110mg/Kg (Table 1). The areal distribution of this metal evokes that of the Nickel and presents, generally a progressive decrease on both sides of the maximum concentration zone of the chromium (Fig.10).

From the distribution maps of all heavy metals mentioned above, we can note that, the highest contents of these metallic elements in the surface sediments of Tangier bay, are situated in the western sector of the bay, in particular between the zone protected by the curved dam of the port and the immediate vicinity of the mouths of the Souani and Mghogha rivers. These high concentrations was found to be related with the rejection of hydrocarbons, the chemicals products and other activities of the port of Tangier, as well as to the domestic and industrial effluents of anthropic origin. To depths of 15ms, the high contents of metals are probably related to the NW littoral transit of Atlantic origin, carrying materials resulting from the domestic wastes located at 500 ms to the West of the port (El Arrim, 2001). The distribution of heavy metals shows also that the pollution degree of the bay varies according to the grains size of sediments, indeed: the high concentrations of metallic elements generally associate with fine sediments of muddy nature and rich in organic matter. The weak concentrations are localised in the east sector of the bay, where prevail the coarse sediment compared to the western sector. Similar results were found in the study zone, mainly the work carried out by Sabhi *et al.* in 2000, which shows that the high concentrations of heavy metal particularly Zn, Cu, Cr and Pb in the marine sediments of Tangier city are in direct relations with the industrial and urban activities that produce a considerable amount of wastes rich in polluting elements. According to the same

Table2:
Multivariable correlation matrix obtained for the bay of Tangier. (C Fr: coarse fraction, F-Fr: fine fraction, CaCo3: carbonate, Org-C: organic carbon)

Variables	C_Fr	F-Fr	CaCo3	Org_C	Pb	Zn	Cu	Cr	Ni	Cd	Co
C Fr	1										
F-Fr	-1	1									
CaCo3	0.05	-0.05	1								
Org_C	-0.25	0.25	-0.05	1							
Pb	-0.20	0.20	-0.32	0.06	1						
Zn	0.18	-0.18	-0.27	0.11	0.74	1					
Cu	-0.46	0.46	-0.41	-0.01	0.75	0.50	1				
Cr	-0.52	0.52	0.07	0.15	0.16	-0.10	0.19	1			
Ni	-0.50	0.50	-0.28	0.01	0.62	0.40	0.91	0.33	1		
Cd	-0.05	0.05	-0.08	0.07	0.85	0.61	0.47	0.30	0.33	1	
Co	-0.34	0.34	0.06	0.06	0.24	0.26	0.47	0.48	0.75	0.13	1

author, the marine pollution degree of Tangier remains relatively low in comparison with other cities of the Mediterranean basin (UNEP/FAO, 1989; WHO/UNEP, 1995).

Continental emissaries: the concentrations of heavy metals range between 105 and 3424 mg/Kg for Zinc (Fig.7), 16 and 610 mg/Kg for Lead (Fig.6), 73 and 269 mg/Kg for Chromium (Fig.10), 22 and 159 mg/Kg for Copper (Fig.8), 23 and 127 mg/Kg for Nickel (Fig.9) and between 0.04 and 0.9 mg/Kg for mercury. These results show that these heavy metal contents exceed far those normally found in the muddy sediments (Boust, 1981). On the other hand, the heavy metals evolution in marine sediments of the continental emissaries shows an increase of metal concentrations from upstream to downstream. The highest contents of these metallic elements are localised to the downstream of rivers, especially in the stations located near to the domestic and industrial wastewaters discharges established along the rivers (Souani, Lihoud, largest pipeline (RP)), but also in the median part of the Mghogha river, just at the exit of the big industrial park of Tangier city. The weakest metal concentrations are generally met to the source of the rivers (El Hatim *et al.* 2002).

Generally, the concentrations of heavy metals in the continental emissaries (rivers) evolve in irregular way from a station to another, increasing gradually upstream to downstream of the rivers. The high percentages of Zinc, Chromium and Lead recorded in the majority of the stations, are probably owed to the presence of manufacture of batteries, and oil refineries

along the rivers (El Hatimi *et al.*, 2002). The results of the geochemical analyses puts in evidence the existence of real chemical pollution more accentuated in rivers bordering the urban and industrialized zones (Lihoud, Souani and Mghogha), compared to rivers of the east sector of study zone (Mlaleh and Chatt), draining only the cultivable natural lands less anthropized. The wastewater plumes discharged to the sea through the major drain (RP), and its propagation thereafter towards the bay by the combined action of NW and NE littoral transit, indicates the critical pollution state and their impact on the coastal marine environmental quality of Tangier bay

To remedy this environmental situation, Amendis (distributor of water and electricity and liquid purification service in the Tangiers-Tetuan region) in the framework of its big project of decontamination and waste treatment of the bay and the beaches of Tangier, has created since 2004 an important major works. One of them is the implantation of a preliminary and primary, station of treatment covered and deodorized, installed to the west of the big dam of the port, close to the largest pipeline of Tangier city (Rp). This station occupies a surface of 10.850 m², surrounded by a protective dam of approximately 310m length and 30m large. There is also the project of construction; of an emissary at sea of 2.90km length and 1.30m of internal diameter, whose extremity will be situated to 43 m of depth. The realization and the activation of these works will probably permit to contribute to the improvement of the fluviate water quality and a better management and protection of the coastal marine environment state of the bay and the

Table 3:
Factor loadings Values of analysed variables obtained for the bay of Tangier from the Multivariate Factorial Analysis

Variables	Factor 1	Factor 2
C Fr	0.01	-0.93
F-Fr	-0.01	0.93
CaCo3	-0.43	0.01
Org_C	0.00	0.26
Pb	0.93	0.16
Zn	0.87	-0.19
Cu	0.77	0.48
Cr	0.03	0.70
Ni	0.65	0.62
Cd	0.77	0.04
Co	0.32	0.59

beaches of Tangiers. From the economic and social point of view, these works will also contribute to the preservation of hygiene and the public health as well as the economic and tourist development of Tangiers city.

Statistical processing

With aim of establishing the relation-correlations being able to exist between the different organic and inorganic parameters analyzed in the superficial sediments of Tangier bay and its continental emissaries (carbonates, organic carbon, heavy metals and sedimentary facies), we used as statistical processing, the Multivariate Factorial Analysis (MFA). In this analysis, the data is carried in a system made up of the two factorial axes, which represent the highest values.

It is a sort of geometrical representation of the variables regrouped in factors. Each factor associates variables which present a better correlation between them or having the same behavior compared to the remainders of the measured variables (Imbrie, 1963; Davis, 1973, Ouddane, 1992 & Laberge *et al.*, 1994).

The results of the multivariable correlation matrix obtained for Tangier bay, show that some metals present high coefficients of correlation between them, mainly couples constituted by Cu-Ni (0.91), Pb-Cd (0.85), Pb-Cu (0.75) and Zn-Pb (0.74) (Table 2). The application of Multivariate Factorial Analysis to the geochemical and sedimentological data of Tangier bay sediments, made it possible to establish the criteria of classifications and to regroup the studied samples according to criteria's of similarity. The statistical results show two factorial axis explaining 63 % of the data variance (Fig.11). The first factor (F1) explains 34 % of the overall variance, the dominant association of heavy metals is constituted by decreasing order of the Factor loadings values by Pb>Zn>Cu>Cd>Ni (Table 3 & Fig.11). This factor presents its maximal significance in close proximity of the Souani and Mghogha rivers mouth, between isobaths 5 and 10m. The second factor (F2) explains 29 % of the model variance, the resulting association is represented by F.fine>Cr>Ni>Co (Fig.11). This factor is well represented at the West extremity of the bay of Tangier. Associations of heavy metals which result from these two factors testify an increasing gradient of pollution of the superficial sediments of the bay. A great part of these metals could have an anthropic origin from the

Table 4:
Multivariable correlation matrix obtained for the continental emissaries. (Grav: gravel, F-Fr: fine fraction, CaCo3: carbonate, Org-C: organic carbon)

Variables	Grav	Sand	F-Fr	CaCo3	Org-C	Cu	Pb	Cr	Zn	Cd	Ni	Hg
Grav	1											
Sand	0.02	1										
F-Fr	-0.23	-0.98	1									
CaCo3	0.25	0.10	-0.15	1								
Org-C	-0.11	0.45	-0.41	0.35	1							
Cu	-0.24	0.55	-0.48	-0.30	0.25	1						
Pb	0.13	0.48	-0.50	-0.28	0.09	0.63	1					
Cr	-0.14	0.19	-0.16	-0.44	-0.34	0.53	0.75	1				
Zn	0.21	0.26	-0.30	-0.05	0.01	0.40	0.42	0.15	1			
Cd	-0.13	0.27	-0.23	0.32	0.01	0.01	-0.07	-0.15	-0.13	1		
Ni	-0.26	0.40	-0.34	-0.53	-0.27	0.72	0.76	0.88	0.28	0.03	1	
Hg	0.52	-0.02	-0.09	0.25	0.17	-0.09	0.14	-0.28	0.13	-0.09	-0.32	1

rivers Inputs and the direct industrial discharges poured in the bay.

In the continental emissaries, the results of the correlation matrix show that some traces metals, in particular nickel, lead, copper, and Chromium, Seems to have a good correlation between them, with positive and significant coefficients of correlation of 0.88, 0.76, 0.75, 0.72 and 0.63 for the couples Ni-Cr, Pb-Nor, Pb-Cr, Cu-Nor and Cu-Pb (Table 4). The results of the Factorial Analysis obtained for the continental emissaries show two factorial axis explaining 57 % of the data variance (fig. 12). The F1 factor explains 35 % of the variance, and regroups by decreasing order of the Factor loadings values the dominant association represented by Pb>Cu>Sands>Ni>Cr (Table 5 & Fig12). This factor presents its maximal significance close to the largest pipeline of sewage water of Tangier city (Rp), and to the downstream of the Lihoud and Souani rivers. The second factor (F2) is less significant than the first one; and explains 22% of the model. The association obtained is composed by CaCo3>C- Org>Hg, the high values of this factor are located along of Souani river, in the median part of Mghogha river and in the downstream of the Mlaleh and Chatt rivers situated at the east of the bay. These two associations could be explained by an industrial anthropic activity, including industries of textile-clothes and leather with 54.22 %, followed by paracheimical units (21.99 %), agroalimentary units (12.79 %), mechanical and metallurgical engineering industries (7.67 %) and electronics industries with 3.32%.

CONCLUSIONS

The superficial sediments of the bay of Tangier are generally of siliciclastic nature. The oriental sector shows the predominance of sandy facies, with decreasing gradient toward the West, The occidental sector, is characterized by fine sediments of muddy nature. The Recent sedimentary dynamics evolution seems to be controlled by hydrodynamic characteristics. The contents of carbonates show an increasing evolution towards the offshore of the bay. The distribution of organic carbon is controlled primarily by the bios physicochemical conditions of the environment. In the continental emissaries, the

Table 5:
Factor loadings Values of analysed variables obtained for the continental emissaries from the Multivariate Factorial Analysis

Variables	Factor 1	Factor 2
Grav	-0.02	0.43
Sand	0.80	0.43
F-Fr	-0.78	-0.51
CaCo3	-0.22	0.74
Org-C	0.22	0.64
Cu	0.84	-0.13
Pb	0.85	-0.15
Cr	0.64	-0.63
Zn	0.49	0.09
Cd	0.08	0.28
Ni	0.79	-0.57
Hg	-0.04	0.51

distribution of granulometric facies shows an increasing upstream-downstream evolution, which results in bad-sorted sediments in relation with an intense anthropic activity along the rivers and pipeline. The distribution of carbonates generally shows an increasing upstream-downstream evolution; the organic carbon concentrations also show a slightly increasing enrichment from upstream to downstream of rivers.

The distribution of heavy metals present in the superficial sediments of Tangier bay, shows that the highest concentrations are located in the western sector of bay, in particular between the zone sheltered by the curved dam of the port and the immediate vicinity of the mouths of the Souani and Mghogha rivers. In the continental emissaries, the high contents of metals are localised to the downstream especially in stations situated near the domestic and industrial wastewaters. The important variations of the metals contents testify to the existence of a contamination of anthropic origin. The principal sources of pollution of the coastal marine environment of the bay and its continental emissaries are directly related to the domestic and industrial liquid and solid discharges who reach the bay by means of the rivers, to the harbour activity, and also in relation with the dispersion of the wastewater plumes discharged to the sea through the major drain of Tangiers city (RP), and its propagation thereafter towards the bay by the combined action of NW and NE littoral transit.

The results obtained from the Multivariate Factorial Analysis and the correlation matrix applied to the organic and inorganic parameters of Tangier bay sediments and its continental emissaries, made it possible to associate and classify the samples and the variables studied in factorial groups. In the bay, the dominant association of heavy metals is consisted by Pb>Zn>Cu>Cd>Ni, while in the continental emissaries, the dominant association is represented by Pb>Cu>Sable>Ni>Cr. These two associations generally show their maximum significance in front of the Souani, Mghogha and Lihoud rivers mouths, close to the major drain (RP) as well as in the West extremity of the bay of Tangiers. These statistical results reveal an increasing gradient of sediments and water pollution by metals. Big part of pollution could have an anthropic origin in direct relation with the industrial and urban activities, which produces enormous amount of wastes poured in the bay via the rivers. Taking in consideration the critical state of pollution of natural environment of the bay, the construction of the station of purification of wastewaters and the emissary at sea constitutes a double importance for the city of Tangier, and will contribute to a better management of the protection of coastal marine environment as well as the economic and tourist development of the Tangier region. on the one hand it contributes to the improvement of the coastal marine environmental quality of Tangier bay and to the economic and tourist development of the area of the other

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