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Physical, chemical and metallic characteristics of the dredging sand extracted in estuary of the Sebou river (Morocco)

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ABSTRACT

Estuary Sebou is one of the most important in Morocco. It is located on the Atlantic coast of Morocco (34 ° 10N, 6 ° 39W) 10 km from the city of Kenitra, and it is the only Moroccan estuary having a port complex. Within the framework of its maintains, the estuary undergoes dredgings. The extract sand is marketed for different purposes without giving importance to its pollution including by metallic elements.

This work focuses on the study of some physico-chemical characteristics and the concentration of some metallic elements in the sediment that are extracted of the estuary and used as marketable sand.

The results showed that this sediment has a high concentration of nitrate and ammonium orthophosphates. Concentrations of Chromium, Copper and lead are higher than those observed in other African estuaries or bays. Thus, dredging sand, while facilitating the navigation at the mouth, has an impact on the marine ecosystem by resuspending metallic elements, organic matter, and chemicals such as phosphates and nitrates fixed on the dredged sediment. So, for any use of sand from the estuary we must take account of metallic, organic and physico-chemical characteristics of this substance.

KEYWORDS

Sand;
Pollution;
Estuary Sebou;
Dredging;
Morocco.

INTRODUCTION

The operations of the maintenance dredging are important from an economic standpoint because they allow the evacuation of the sediment clogging the navigation channels and limit the depth of the estuary mouth and docks[1]. Similarly, some products edging such as the extracted sand are valued. In fact, this sand is used in civil engineering in the sector of construction and public works. Thus, in the estuary of Sebou which is located near the city of Kenitra (Morocco), this product is stored and sold at the platform Mehdia.

Note that in Morocco, as part of maintenance dredging operations, necessary for the maintenance of one optimum level of port activity named DRAPOR (a company dredging port) extracts by dredging in all ports of the Kingdom about an annual volume of 3,000,000 m^3[2].

Furthermore, many studies on the river Sebou, that supplies water the estuary, showed that this river is heavily polluted especially at its lower part. The training of pollued products from its upstream to its downstream is the cause. So, the estuary is regarded as a depository of chemical pollutants and heavy metals. We cite of them Jaghror et *al*. (2013)[3] and Ouzair et *al*. (2012)[4]. Similarly, according to other works, such as that of Jonathan and *al*. (2011)[1], the dredging in estuaries allows a resuspension of the adsorbed sediments creating so a high level of turbidity in the estuary and therefore a chemical relargation of many pollutants in the water thereby affecting the marine environment (Figure 2).

Thus, the purpose of this research is to study the impact of dredging on the physicochemical and metallic parameters of the surface sediments of the estuary of Sebou.

MATERIALS AND METHODS

Study site

It is located on the Atlantic coast of Morocco (34 ° 10N, 6 ° 39W) 10 km from the city of Kenitra and it has an arm form of the ocean that extends over a distance of 15 Km roughly oriented northwest from upstream to downstream[5]. Sebou river crossed the Gharb plain which belongs to the nearby fields of the Rif mountains and its bedrock consists of soft soil, marl and flysch covered by more consolidated sandstone scales[6].

Figure 1 : Aerial photo of the estuary of the river "Sebou" showing a plume of suspended solids. (DRAPOR, 2007)

The hydropeaking amplitude, noted in the mouth of Sebu estuary varies from 0.75 cm at low tide to 2.3 m at high tide during the neap tide; but, it can reach 3.10 m at Whitewater[7, 8, 6]. The water velocity varies from 0 to 0.82 m / s. The filling of the estuary is performed after 2 hours, while its drain is not completed until after about 5 hours[7, 6]. The emptying and the filling of the estuary are mainly from the bottom[9].

The depth ranges between 1 and 10 m. The maritime dominance extends up to 15 km from the mouth. The sea uncorked of the estuary is channeled through two parallel jetties crossing a sandbar (alluvial fan) (Figure 2).

The volume of trapped annually in the estuary materials is estimated at 600,000 m^3, of which 70% is deposited at its maritime part[2]. The dredging volume is estimated at 1 million m^3. A maintains of the coast at - 7m of the navigation channel of the entrance to the estuary to the port of Kenitra requires a dredging of 4,000,000 m^3[10].

Physicochemical and metal analysis of sediments

Our study is based on an analysis of some chemical physical parameters and heavy metal of the surface sediments which were taken in five stations distributed along the estuary of the river Sebou (Figure 2).

The stations are designated as follows:

- S1: It's located 10 km upstream from the collector of industrial discharges of CMCP plant;
- S2: It is located near the Oil Sharifian Company and wastewater of MCPC Society, it receives the impact of industrial discharges of

TABLE 1: Distribution of dredging volumes at the estuary mouth of Sebou[10].

Section	Associated dredging volume (m^3)	Percentage of dredging
Southern Channel downstream	150 000	30%
Channel ferry	240 000	48%
Fishing port of Mehdia	10 000	2%
Port of Kenitra	100 000	20%
total	500 000	100%

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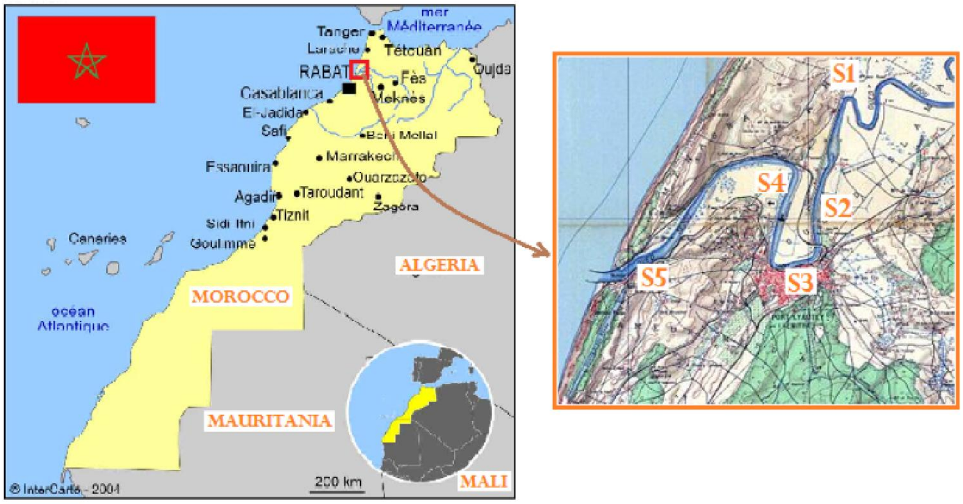

Figure 2 : Location of study sites (S1, S2, S3, S4 and S5) in the estuary of the river Sebou

TABLE 2 : Values of the measured physico-chemical parameters.

Parameters Stations	pH	Electic conductivity(mg/kg)	Amonium(mg/kg)	Nitrates(mg/kg)	Ortho-phosphates(mg/kg)
	8,03	0,98			
S1	7,98	1,33	25	33	25
	8,1	2,11	17	56	51
	7,91	1,37			
S2	7,79	3,44	31	58	20
	8,05	2,93	91	142	12
	7,73	2,91			
S3	7,68	4,16	35	89	15
	7,79	4,61	68	193	18
	7,58	3,90			
S4	7,46	5,70	70	91	13
	7,65	5,09	15	40	10
	7,46	4,61			
S5	7,4	6,15	24	56	11
	7,6	5,19	11	39	9

these units;

- S3: It is situated downstream the port of Kenitra, it receives the wastewater from of Kenitra city;
- S4: It is situated between the ore port and fishing port;
- S5 is located near the mouth of the estuary.

Sampling of sediments

Three seasonal samples were taken at low or average tide in five sampling stations S1, S2, S3, S4 and S5 which were distributed along the estuarine zone (Figure 2). The samples were bagged in plastic food and stored at 5 °C. A mixing was to obtain a homogeneous mixture of the sample; so, we have a representative sample in every the studied station.

Seven physico-chemical and metallic parameters were evaluated in the dredging sand : Electric conductivity, the concentrations of Ammonium, Nitrates, Total phosphorus, chromium, Copper and Lead.

The samples were seasonal. For the physicochemical parameters, two to three samples were taken at low or average tide in five stations. But, for the metallic elements a fourth sample was conducted in the spring season.

Comparison of results with previous studies

To identify the influence of the maintenance dredg-

TABLE 3 : Values of the measured metallic element parameters.

Paramètres Stations	Cr (mg/kg)	Cu (mg/kg)	Pb (mg/kg)
	57,201	25,657	9,370
S1	79,545	27,433	15,303
	40,497	20,248	9,626
	53,927	25,145	6,168
	62,727	28,197	8,824
S2	54,365	26,772	18,724
	53,773	25,554	8,779
	45,229	23,422	46,239
	41,931	22,646	5,969
S3	62,159	21,750	8,618
	50,721	21,985	9,736
	45,643	21,742	6,307
	16,972	10,183	4,138
S4	30,235	11,663	6,040
	18,590	9,458	5,870
	35,015	14,760	6,909
	24,592	15,404	8,216
S5	24,241	16,416	9,083
	26,856	11,058	7,267
	23,929	13,319	4,063

ing operations at the estuary of Sebou, the results of our work after dredging were compared with those made by other researchers made before the actual operation.

RESULTS AND DISCUSSION

Results

Physicochemical parameters

For the various measured parameters, the values are noted in TABLE 2 and 3:

Water pH

The pH of sediment is neutral to slightly alkaline and varies between 7.4 and 8.1. This neutrality is due to the buffering of waters in contact with the sediment effect. Add, we noted that the pH of the sediments of the estuary decreases from upstream to downstream, where the content of sediments in organic matter increases in low water.

Electrical conductivity

The evolution of electrical conductivity variation was proportional to the inverse of the pH changes and follows a concentration gradient increasing from upstream to downstream of the estuary. This is explained by the contribution of organic and mineral matter at stations S2 (industrial zone), S3 (collector of domestic wastewater) and the effect of the addition of salt water from the sea (S4 and S5). In addition, we noted that within each station, the pH is varies according to the seasons. The lowest value (0.98 mg / kg) was noted at S1 and the highest (6.15 mg / kg) in S6.

Ammonium

The spatio-temporal evolution of the ammonium content of soil showed an increase of the ammonium concentration of S5 (11 mg / Kg) to S2 (91 mg / Kg). In S5, the concentration was 24 mg / kg in September. In S2, a maximum value of 91 mg / kg was noted in December. But, in S5 this value was minimal (11 mg / kg). Also, in S4, we noted a low value (15 mg/kg).

Moreover, the increase in the content of ammonium in sediments from the leaching of agricultural products and wastewater discharges from the city of Kenitra, which are rich in organic matter. Furthermore,

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Nitrates

The results showed that, in the sediment, the levels of nitrate (NO3-) varies as a function of time and space. Indeed, in September they ranged from 33 mg / kg, registered in S1, 193 mg / Kg, noticed in S3.

The same trend was noticed in December, which were a period of heavy rain, but with higher values †; the leaching of fertilizers used in agriculture and wastewater discharges made †during this period could the one the main causes of the variation of this concentration.

Orthophosphorus

The results showed that the maximum level (51 mg / kg) was noted in the S1 station in December and the low concentration (9 mg / kg) was noted in the S5 station downstream of the estuary in September. The increase in the concentration of total phosphorus in sediments in December is often due to leaching of phosphate fertilizers used in agriculture. But according to Boston et *al*. (1982)[11], the sediment can be considered as a storage tank of the total phosphorus. Their adsorption and release by the sediment depending on their content in the sediment, and the physicochemical parameters in the aquatic environment and the sediment content of organic matter.

Heavy metals

The contents of heavy metals in sediment were higher in the sediment than in water; So, there is a storage of metals in sediments.

Chrome

The changes in levels of chromium in the sediments of the estuary show very high values †and a decreasing concentration gradient from upstream to downstream of the estuary. The results showed that the concentration of chromium between 16,972 mg/kg noted in S4 and 79,545 mg/kg noted in S1. This shows a high degree pollution of the estuary by the chrome. Moreover, the low chromium concentration in the sediment of S4 and S5 can be explained by the effect of the tides which is important at those stations allowing a dispersion of metallic elements. In addition, the concentration of Chrome is higher in September, compared with December, which can be explained by the dilution effect of continental water that was provided during the rainy season

Moreover, the results that we found for chromium confirm those found in 1999 by Azzaoui[12] which were between 70 and 150 mg / kg in the sediment.

Copper

In the sediments, the concentration was between 9,458 mg/kg noted in S4 and 28,197 mg/kg noted in S2. Also, the evolution of the Copper concentration follows the same trend as of for chromium (Fig.). Indeed, the copper concentration decreases from upstream to downstream (from the station S1 to S4). Then, it undergoes a slight increase in S5. This decrease can be explained by the dispersion of suspended solids which are adsorbed by chemical particles with copper along of the estuary transit. Furthermore, we found that levels are similar to those reported in 1999 by Azzaoui [12] and vary between 26 and 36 mg / kg of sediment.

Lead

The results show that the level of lead in the sediment follows roughly the same trend of copper level which decreases along the downstream of the estuary; except the S2 station, which has in December a peak concentration and that is probably due to the effect of wastewater discharges of the Moroccan Society of cardboard and paper industries, and National Electricity Office. Downstream, tides generate the dispersion of metals adsorbed to sediments where we have noted a low concentration of lead. Add, the results showed that the concentration of Lead between 4,063 mg/kg noted in S5 and 46,239 mg/kg noted in S2.

Discussion

As reported by Berube (1994)[13], a sand mining causes physicochemical changes in surface water related to increased turbidity and mainly resuspension of large quantities of fine particles, this will trigger a sediment transport plume (cloud sea) (Figure 2). Also, it aggravates the eutrophication during the degradation of the organic fraction and that will be even larger than the duration of action of the currents will be important[14]. Thus, theoretically, a dredging sand estuary must lead many changes in physico-chemical characteristics of water and in the sediment structure of the estuary.

The uncontrolled sand extraction of a beach has usually a negative impact and prominent and immediate risk to the surrounding environment including a break in the dynamic equilibrium of beaches, a contamination of the freshwater from salt water and a disruption of surrounding agricultural land[15]. But, because of the increased need of this basic substance in all construction work and which is the main constituent of estuarine sediments, the sand is extracted from this hydrosystem by dredging. However, any dredging activity has multiple and unavoidable impact on the balance of the coastal ecosystem such as physical changes: increased turbidity, chemical changes in the form of reduced content in oxygen in water, and biological changes with possible toxic effects on living organisms. Indeed, reactions that occur during dredging operations are extremely varied, often reversible, and occur both at the site of dredging during transport and after deposition. These reactions may have antagonistic effects, some are leading to a fixation of metal elements initially in solution on the sediment. Contrarily, others are leading to a solubilization of the metal elements initially fixed[14]. But in all cases, the sediment is a permanent depository of metal element and form a kind of reservoir acting as a relay element in the fundamental geochemical cycle[16]. Thus, various key mechanisms ensure the accumulation of metals in sediments and thus regulate the exchanges which are possible between water and sediment: adsorption phenomena , phenomena of co -precipitation with the Oxy / hydroxides of iron and manganese and carbonates , phenomena of direct precipitation of heavy metals, and complexing phenomena flocculation with organic material , the incorporation of metals in the inorganic crystalline mesh[14].

Moreover, unlike organic pollutants, practically heavy metals have not been the biological or chemical reaction of degradation and could therefore be accumulated in food chains. So, they are found in toxic concentrations in many marine organisms[17-19].

Moreover, the problem of exploitation of stocks sand comes from their non-systematically renewable nature. The reconstruction of a sand deposit can take thousands of years and involve different geological episodes. The destruction of a stock of sand can also have secondary effects on ecosystem functioning.an In addition, this resource (sand) which is at the interface between nature and society is fragile requires an integrated inventory management to tend to the preservation of the system without altering any possibility of sustainable development. The difference lies in the operating force exerted on the resource. A sustained and non-dimensioned effort may be the reason for the disappearance of environments and associated ecosystems: it is therefore necessary to take provisions to limit the impacts on ecosystems and to find alternatives to immersion mainly when sediments have undeniable toxic characteristics[20].

The variation in the content of some metallic elements could be related to the variation of the degree of water salinity along the estuary. Indeed, a large number of pollutants, and especially certain metals or metalloids, bind strongly on inert or living, organic or inorganic particles, constituting a maximum turbidity. The material quantities will be evicted based on the flow regime, low flow or flood, and on the tidal coefficient (bright or neap). At their expulsion, sedimentary particles pass through a salinity gradient from freshwater to a closed salinity of seawater (35 ‰). Changing salinity which is an ionic strength of the environment, will have an impact on the binding power of the metal ions. So, depending on the period, estuaries were considered sources of metals[21].

For the three metallic elements studied the concentrations noted in the Estaire Sebou are superior to those reported by KEUMEAN et *al.* (2013)[22] in the sediments of the estuary of the River Comoé in Grand-Bassam (South-eastern Côte d'Ivoire).

The origin of these metallic elements has been often anthropogenic[23]. But, the distribution of the metal element content in the sediment of an estuary or bay depends on the action of many factors including the particle size of the sediment. In fact, the highest values are found in general in the finest sediment fraction[22; 24-26].

Therefore, it appears that the dredging operation of sand has no significant effect on the physico-chemical charcteristics or the concentration of heavy metal element of the estuary sediments. But, even if the practice of dredging is not to question, it cannot be pursued if we take into account the constraints of preservation of coastal ecosystems. Indeed, it is recognized that sediment dredging of disposal at sea is a way of transfer of contaminants into the marine environment. Further note that the estuary of the river Sebou is considered as the most polluted one. It receives many anthropogenic pollutions (domestic, industrial and agricultural) and the entire watershed of the cities that are crossed by the river Sebou

In addition, other factors may intervene to disrupt the stability of these factors including the tide that according to Mergaoui et *al*. (2003)[7] led to a transformation of the physicochemical characteristics of the estuary, the release of chemicals and heavy metals adsorbed to sediment, and the factor "season" which, according to ED-Darouich (2006)[27], could enrich the water of the estuary by the suspended matter which comes of erosion in variable quantities depending on the season .

CONCLUSION

Superficial sediments have richness in organic matter, in nitrates and in phosphate. This richness was due to the domestic waste contribution and the leaching water from agricultural soils. Also, the fine sediment (clay, silt) retains much more water and organic matter that the coarse sediments.

The average concentrations of heavy metals which were accumulated in the superficial sediment vary from 20 to 68 mg / kg for the chromium, 10 to 28 mg / kg for the copper and 5 to 28 mg / Kg for the lead. These high levels of heavy metals reflect a state of significant micropollution, confirming the ability of these sediments to absorb metallic elements according the physico-chemical conditions the aquatic environment.

The dredging of sand and the estuary dredge, while allowing the ease of navigation of the boats at the channel mouth, it has an impact on the marine ecosystem by resuspending many metal elements and organic matter and chemical elements, such as phosphates and nitrates, that are fixed on the dredged sediment which increases so the water turbidity and the pollution of the estuary and creates a significant stress for the species of the medium.

Moreover, the dredging operation is vital for maritime traffic and ports, sand dredging remains an alternative solution for protect beaches and coastal dunes and to remedy the damage. However, the use of stocks of sand, must go through the integrated management, taking into account the ecological balance of the extraction zone.

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