American Journal of Applied Chemistry
2022; 10(5): 114-119
http://www.sciencepublishinggroup.com/j/ajac
doi: 10.11648/j.ajac.20221005.11
ISSN: 2330-8753 (Print); ISSN: 2330-8745 (Online)

Physicochemical Parameters and Trace Metal in Marine Sediment from Bargny Coast (Senegal)

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To cite this article:

Birame Ndiaye, Momar Ndiaye, Benita Perez Cid, Abdoulaye Diop, Ibrahima Diagne, Dame Cisse, Cheikh Tidiane Dione, Maoudo Hane, Mame Mor Dione, Sitor Diouf, Seydou Ba. Physicochemical Parameters and Trace Metal in Marine Sediment from Bargny Coast (Senegal). *American Journal of Applied Chemistry*. Vol. 10, No. 5, 2022, pp. 114-119. doi: 10.11648/j.ajac.20221005.11

Received: August 1, 2022; **Accepted**: August 19, 2022; **Published**: September 16, 2022

Abstract: Marine sediments samples from Bargny coast (Senegal) were analyzed by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The microwave acid digestion was also employed for metals (Cd, Pb, Cr, As) determination. The physicochemical parameters (pH, temperature, salinity, electrical conductivity) measured complied with European water standards. Fine fraction (< 63 µm) of sediments was used for extraction and determination of metallic trace elements. This study shows the presence of metallic contaminants in the marine sediments of the Bargny area. The marine sediments samples analyzed show practically similar metal contents during three sampling periods. The analytical results show that content of metallic trace elements found in marine sediments was in the following order: As> Cr> Cd> Pb (µg/g). This pollution can be attributed to the two factories located in this area: a coal-fired power station factory and a cement production factory (SOCOCIM INDUSTRY). This study shows the possibility of using sediment as an indicator of pollution because of its high capacity to accumulate pollutants. The ANOVA statistical analysis of results shows significant differences between metal contents of sediments studied during different campaigns. The assessment shows that sediments of Bargny coast do not present any significant risk of toxicity for living organisms in this aquatic system.

Keywords: Physicochemical Parameters, Trace Metal, Marine Sediment, Pollution, Bargny Coast, Senegal

1. Introduction

In recent years, heavy metals have been the main pollutant of aquatic ecosystems, particularly marine sediments [1-5]. Due to their toxicity, widespread sources, biodegradable properties, and cumulative behavior, trace metals are of particular environmental concern [6]. Heavy metals that are poorly soluble in water are easily adsorbed and accumulated in sediments [7]. Therefore, coastal sediments are still considered the ultimate sinks for trace metals [8]. On the other hand, some metallic trace elements cannot be permanently fixed by sediments and will be released to the overlying water, when environmental conditions (such as salinity, pH, temperature and electrical conductivity) change [9, 10].

Some trace metals such as chromium (Cr) and arsenic (As) are essential elements for marine organisms in environment, required by organism for normal physiological activity [11]. Nevertheless, trace metals such as cadmium (Cd) and lead (Pb), which have no essential biological functions, are toxic even at low concentrations [12-14]. Environmental contamination by heavy metals is a global phenomenon that has attracted a lot of attention. The main objective of this work is to determine the physicochemical parameters and the content of metals (arsenic, cadmium, lead, and chromium) in marine sediments from Bargny coast. To our knowledge, no study determination of the content of heavy metals in the sediments has been made in the coastal area of Bargny. It seemed important to us to research the levels of metals present in marine sediments of this area to prevent possible contamination of the population. This study is part of the

search for sources of pollution in the coastal ecosystem of Bargny and appropriate solutions to improve its quality.

2. Material and Methods

Town of Bargny occupies the western coastal part of Senegal and is crossed from East to West by national road n°1 which cuts it into two parts. It is located about thirty kilometers from Dakar and constitutes the eastern limit and the gateway to the whole constituting the Dakar-Guediawaye-Pikine-Rufisque-Bargny conurbation. It should be noted that the city of Bargny is physically included in the department of Rufisque while no text specifies the limits of the 2 entities. This does not facilitate cohabitation and friction is felt both between the two municipalities to the west of Bargny (economic stake due to the presence of a SOCOCIM INDUSTRY cement factory and a coal-fired power station) and towards the is between the municipality of Bargny and the rural community of Sebikotane (land issue).

Climate of the Bargny area is characterized by alternation of a dry season (October-June) in general and a rainy season which lasts three months (July-September). It is of the Sudano-Sahelian type and is strongly influenced by the sea. Located between the 200 and 500 mm isohyets, the commune receives rain from June to September. These irregularly distributed rains reach their maximum in August or September.

Wind regime has two distinct characteristics. North sector trade winds dominate during the period from November to May. The Harmattan (NNW) blows intermittently generally in May. But it is noticeably softened by the trade winds, which takes away a good part of its own characteristics. As for the monsoon winds from the W-SW sector, they mark the onset of wintering and only last for this season. The frequency of winds blowing NNW and W-E means that the city of Bargny, in particular the neighborhoods closest to the plant, Ndiolmane, Kip-Carrieres and Castors 3, Sancubgeej and Ngouye Daaga, Ngud, Mboth and Missirah receive most of the dust issued by the SOCOCIM factory. Also in the south-east of the commune, the districts of Sindou and Miname suffer from pollution from limestone quarries and the coal-fired power station.

All chemicals used were of analytical-reagent grade from Merck (Darmstadt, Germany). Ultrapure water (Millipore Milli-Q System) was used throughout all the work. The calibration standards were prepared from the stock solution of metal. All glass and plastic containers and materials were soaked in a 1.5% w/v HNO_3 solution for 48 h and rinsed with ultrapure water three times before use.

From January 2021 to July 2021, three sampling campaigns were carried out at low tide in the coastal area of Bargny. Maps (Figure 1) show both study areas as well as the situation of the corresponding sampling points.

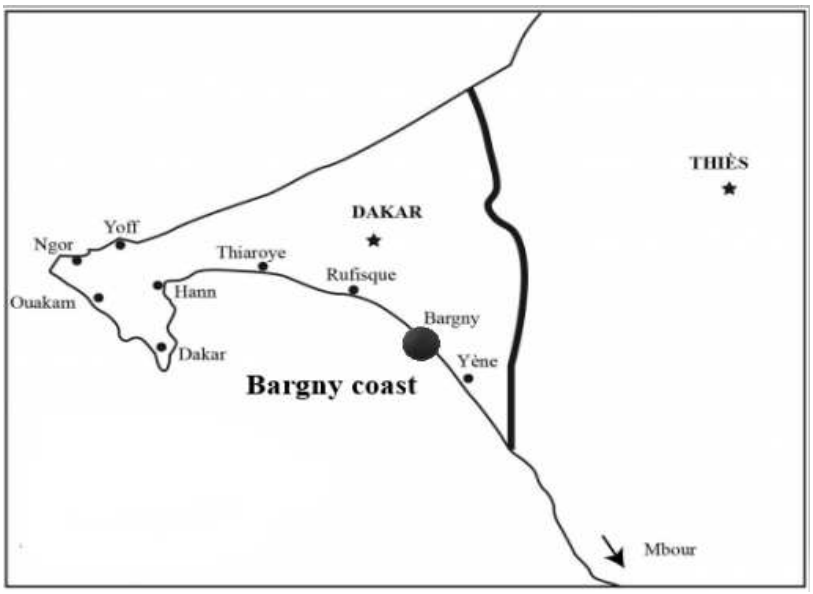

Figure 1. *Location of Bargny area in Dakar coast (Senegal).*

Surface sediment sampling was carried out using a small Van-type grab Veen, following the reference methods for marine pollution studies [15]. Sediments sample were stored in polyethylene bottles, then placed in the dark in a cooler (4°C). In laboratory, sediments were placed in a freezer (-20°C). After drying at in the oven (60°C) for 24 hours, the sample was pre-sieved over 2 mm in order to remove pieces of shells, branches and leaves before sifting. Sediments (<63 µm) were kept in plastic bottles, with plastic tape around the closure in order to protect them from humidity, then stored in a dark and cool cabinet (20°C) for analyzes.

Determination of physicochemical parameters. Water temperature, pH, Electric Conductivity, and salinity were performed immediately after sampling using pH-meter, model "HANNA instruments pH/conductivity HI98129."

Heavy metal in marine sediment was analyzed following a sample preparation method previously described [16]. A sample (0.30 ± 0.01) g of homogenized sediment was mineralized with 4 mL of concentrated nitric acid (65% w/w) and 2 mL of hydrochloric acid (37% w/w) in the PTFE vessel

of the Parr reactor. The vessel was closed and heated in the microwave oven during 2 min at 450 W of power. After this, the reactor was allowed to cool in an ice bath, during 15 min, before opening. The resulting solution was filtered and quantitatively transferred into a 25 mL volumetric flask and diluted to volume with ultrapure water.

Arsenic (As), lead (Pb), cadmium (Cd), chromium (Cr) were determined by using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). A domestic microwave oven (Moulinex, 900 W power) was used for microwave heating. A 45 mL capacity Parr reactor (model 4782) was used for acid digestion. A centrifuge (Kubota 5100) was used for a rapid separation of solid-liquid phases. Statistical analysis was performed with the software SPSS (v19) for Windows.

3. Results and Discussion

During sampling, pH, temperature, salinity and electrical conductivity were measured for the different water samples studied. Table 1 presents the average values of some physicochemical parameters obtained in marine sediments for the three campaigns. The temperature measured in the samples from the Bargny coast varies between 29.6°C and 30.4°C, which is in line with European water standards. The pH of seawater at the sites studied is neutral to slightly basic with values varying between 7.7 and 8.4. The salinity of the surface waters of the Dakar coast varies between 22.3‰ and 29.9‰, while the relatively high values of the electrical conductivity (1789-2317 µS/cm) indicate the highly mineralized nature of the coastal waters of the municipality of Bargny (city of Dakar). The preliminary results, of the introduction of the presence of mineral pollutants, can be easily associated with a significant acidity. The parameters measured were followed by qualitative assays of the metal ions likely to be present in the marine sediment samples.

Table 1. *Physicochemical parameters found in marine sediment from Bargny coast.*

Sampling points	pH	Temperature (°C)	Salinity (‰)	Conductivity (µS/cm)
January 2021				
B1	8.1 ± 0.7	29.6 ± 1.4	27.7 ± 1.3	2317 ± 13.5
B2	7.7 ± 0.9	30.2 ± 1.5	29.9 ± 1.6	2116 ± 17.7
B3	8.3 ± 1.1	30.4 ± 2.0	22.3 ± 2.1	1956 ± 23.3
B4	8.4 ± 0.8	31.1 ± 1.7	28.9 ± 1.7	1789 ± 19.6
April 2021				
B1	7.4 ± 1.3	28.3 ± 1.1	28 ± 2.1	2032 ± 14.1
B2	7.9 ± 1.0	31.0 ± 2.6	30.3 ± 2.5	2026 ± 15.5
B3	7.8 ± 1.6	27.7 ± 2.3	24.6 ± 1.9	2004 ± 21.3
B4	8.0 ± 1.2	29.6 ± 1.4	27.4 ± 2.0	1448 ± 17.9
July 2021				
B1	9.2 ± 1.2	30.4 ± 2.2	26.4 ± 2.5	2104 ± 13.3
B2	8.4 ± 1.4	32.0 ± 2.7	31.3 ± 1.7	2221 ± 20.4
B3	8.8 ± 1.8	29.1 ± 1.9	27.5 ± 1.5	2054 ± 24.6
B4	9.1 ± 0.9	30.3 ± 1.2	29.1 ± 1.9	1511 ± 19.2

Analysis of marine sediments reveals presence of heavy metals (As, Cd, Pb, Cr), of varying concentrations at different sites studied. Content of heavy metals found in marine sediment samples is shown in Table 2 and Figure 2. Content of heavy metals in marine sediment samples (<63 µm) was observed in different areas studied. Contents of heavy metals in the fine particles of marine sediments were in the following order: As> Cr> Cd> Pb (µg/g). The maximum heavy metals in arsenic (32.5 ± 2.3 µg/g) were observed at station B2 and the minimum value was found (10.6 ± 1.4 µg/g) at station B1. A maximum of chromium was analyzed (19.1 ± 1.5 µg/g) at station B2 and a minimum was recorded (6.1 ± 1.1 µg/g) at station B1. Arsenic (As), a naturally occurring element, is a global contaminant found in rocks, soil, water, air and food. Arsenic is a highly toxic and carcinogenic element for humans. Humans can be exposed to arsenic through ingestion of food and drinking water.

Lead (Pb) content was measured (6.2 ± 0.9 µg/g) at station B4 and a minimum value was observed (1.7 ± 0.8 µg/g) at station B2. A maximum of cadmium was analyzed (12.6 ± 0.3 µg/g) at station B4 and a minimum was observed (3.5 ± 0.2 µg/g) at station B1. Moreover, these values found, were quite similar in all sampling points with non-significant variation.

In this study, we recommend that regulatory bodies control the entry of heavy metals from different sites to protect the aquatic environment and human health. Metallic elements in marine sediments refer to some heavy metals with significant biological toxicity, including cadmium (Cd), lead (Pb), chromium (Cr), arsenic (As), etc. The contamination of marine sediments by heavy metals has gradually increased in recent years; which has led to serious deterioration of the environment. The Figure 2 shows the distribution of heavy metals in marine sediments following the sites studied of Bargny coast. All the values are expressed in µg/g (dry weight) and they are given as mean of four separated determinations and their standard deviation. The results indicate that marine sediment accumulate much more arsenic (As) than other metals.

Table 2. *Trace metals concentrations in marine sediment samples from Bargny coast.*

Trace metals	B1	B2	B3	B4
January 2021				
Cd	3.5 ± 0.2	4.1 ± 0.9	9.5 ± 1.0	12.6 ± 0.3
Pb	3.2 ± 0.6	1.7 ± 0.8	4.1 ± 0.6	6.2 ± 0.9
Cr	6.1 ± 1.1	19.1 ± 1.5	17.8 ± 1.6	9.1 ± 1.7
As	10.6 ±1.4	32.5 ± 2.3	30.7 ± 1.8	12.7 ± 1.2
April 2021				
Cd	2.7 ± 0.3	3.5 ± 1.1	9.1 ± 1.2	8.2 ± 1.1
Pb	3.0 ± 0.2	1.3 ± 0.9	3.4 ± 0.9	4.4 ± 0.6
Cr	5.6 ± 1.2	18.2 ± 1.8	15.4 ± 1.8	10.2 ± 1.3
As	9.4 ± 0.8	30.4 ± 1.8	27.6 ± 2.1	11.2 ± 1.8
July 2021				
Cd	4.1 ± 0.9	3.8 ± 0.6	10.3 ± 1.3	11.3 ± 0.8
Pb	3.7 ± 0.8	2.1 ± 0.7	5.4 ± 0.9	6.8 ± 0.6
Cr	6.0 ± 1.0	20.3 ± 1.1	16.5 ± 1.2	11.2 ± 1.6
As	9.8 ± 1.2	33.2 ± 2.6	30.7 ± 2.6	13.4 ± 1.9

Maximum arsenic content of heavy metals was observed at station B4. Current results for arsenic (As), chromium (Cr), cadmium (Cd) and lead (Pb) were compared to sediment reference values [17, 18]. Results obtained in this work are also compared with data for the surface sediments of Gulf of Izmit [19]. Current median

values also show close agreement in most cases with global median values for surface sediments [20]. As we all know, cadmium was a non-essential element of human health with high biological toxicity; it is mainly accumulated by surface sediments and enters the body mainly through the digestive system [21].

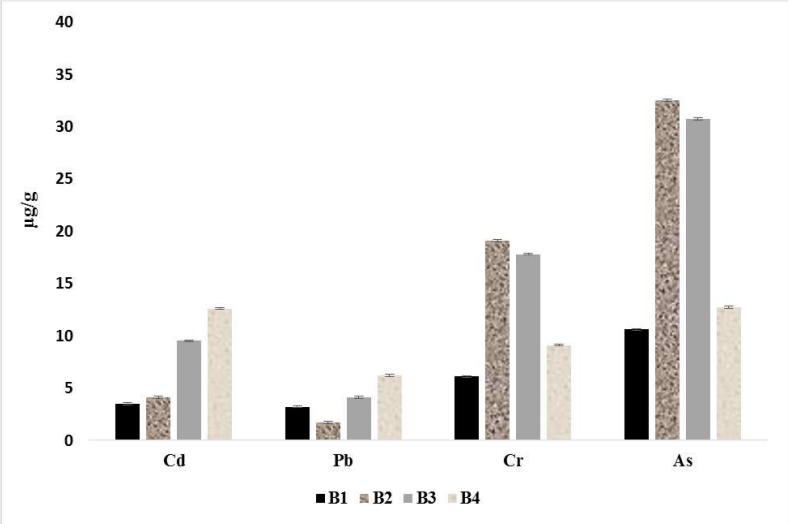

Figure 2. *Distribution of metals in the sediments following the sites studied.*

Toxic level of chromium in sediment is around 6 to 19 µg/g [22], and compared to this value, chromium measurement was very low in the study area. The addition of artificial fertilizers and pesticides leads to increased lead levels in agricultural soils. Lead comes from industrial and domestic wastewater, and air pollution resulting from the release of vehicle exhaust and the incineration of fossil fuels in the environment [23].

Additionally, toxic elements can also stabilize due to high soil pH, which can lead to lower element concentrations in the soil solution. This can limit uptake of elements from soil solution and translocation into plant tissues [24]. Cadmium and lead are non-essential elements and their presence, even at very low concentrations, has adverse effects on human health [25]. Cadmium in the diet accumulates mainly in the kidneys and liver [26, 27].

This pollution can be attributed to the two factories located in this area: a coal-fired power station factory and a cement production factory (SOCOCIM INDUSTRY). In addition, anthropogenic emissions may also be provided by the small port facilities located along the coast of Bargny. In this study, we recommend to regulatory bodies to control the entry of metallic trace elements from different points to protect the aquatic environment and the health of the population of Bargny. Heavy metals in sediment refers to some important heavy metals of biological toxicity, including cadmium (Cd), lead (Pb), chromium (Cr) and arsenic (As), etc. Presence of heavy metals in sediments can lead to environmental deterioration. The ANOVA statistical analysis of results shows significant differences between metal contents of sediments studied during different campaigns. The assessment shows that sediments of Bargny coast do not present any significant risk of toxicity for living organisms in this aquatic system.

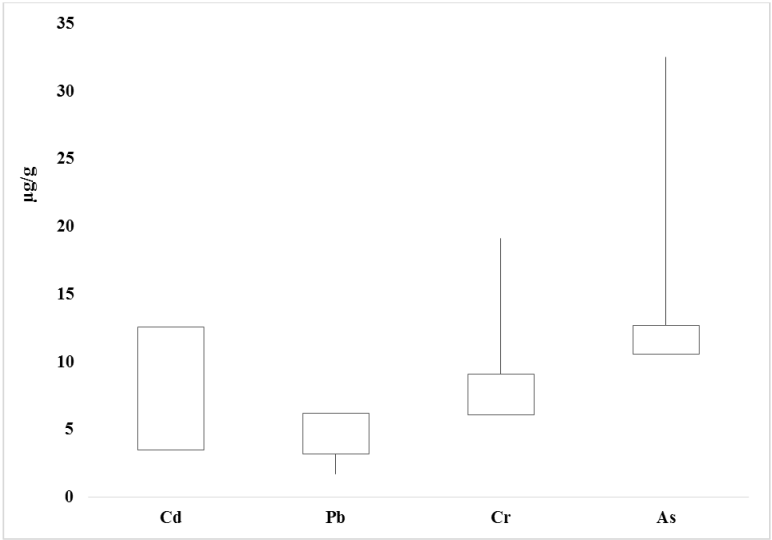

Figure 3. *Average levels of metals in the marine sediments according to the sites.*

4. Conclusion

In this work, we determined the physicochemical parameters (pH, temperature, salinity and conductivity) and the content of certain metals (As, Cd, Pb, and Cr) in the marine sediments from Bargny coast. The analyzes were carried out by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to measure metallic elements such as arsenic, cadmium, lead and chromium. This study shows the presence of metallic contaminants in the marine sediments of the Bargny area. The content of heavy metals in the fine sediment samples was in the following order: As > Cr > Cd > Pb (µg/g). This pollution can be attributed to the two factories located in this area: a coal-fired power station factory and a cement production factory (SOCOCIM INDUSTRY). It is therefore necessary to install wastewater treatment plants in the study areas to assess the quality of the discharge water on the one hand and to improve the state of the coastal environment of the municipality of Bargny somewhere else. The ANOVA statistical analysis of results shows significant differences between metal contents of sediments studied during different campaigns. The establishment of a biomonitoring network of the impacts of pollution along the coast can be considered. However, we propose in a later work to study the content of other metals potentially dangerous for human health such as mercury as well as the evolution of their concentration as a function of time.

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