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Research Article

Evaluation of the Physico-Chemical Parameters of the Sediments of the Tsieme River in Brazzaville (Republic of Congo)

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Abstract

Population growth, accompanied by rapid urbanization, is the cause of many disturbances in natural environments. The presence of physical and/or chemical contaminants in sediments causes toxic effects in aquatic environments. This work aims to determine the physicochemical parameters of the sediments of the Tsiémé River in Brazzaville during the dry and rainy seasons. Four (04) sediment samples were taken per season and analyzed by potentiometric, X-ray diffractometric and Robinson methods. The results obtained show that quartz is the only mineral species detected. The particle size distribution of the sediments shows particles of different sizes in the order of coarse sand > fine sand > coarse silt > fine silt. The sediments of the Tsiémé River are moderately acidic with pH values varying between 5.75 and 6.69 in the dry season and between 6.38 and 7.13 in the rainy season. The low values of electrical conductivity ranging from 18 to 173 µs/cm in the dry season and from 13 to 86 µs/cm in the rainy season characterize the low mineralization of the sediments. The percentage of total nitrogen varies from 0.004 to 0.006% in the dry season and from 0.00 to 0.005% in the rainy season. Similarly, the total phosphorus rate fluctuates between 0.007 and 0.07% and from 0.06 to 0.1% in the dry and rainy seasons. The organic matter contents vary between 0.248 to 3,549% and 0.038 to 0.114% in the dry and rainy season. These results indicate the absence of mineral and organic pollution of the sediments. Thus, the sediments of the Tsiémé River do not present imminent risks from a physicochemical point of view.

Keywords

Evaluation, Physico-Chemical Parameters, Sediments, Tsieme River, Brazzaville

1. Introduction

Coastal hydrosystems (rivers, lakes, estuaries, lagoons, oceans, etc.) are nowadays subject to strong anthropogenic pressures, in particular urbanization, tourism, agriculture, fishing, industrial expansion and mining [1, 2]. These activities are responsible for the release of various organic and inorganic pollutants that contribute to the pollution of aquatic. Concentrations of these contaminants in some waters, sediments and living organisms have reached alarming levels from an ecotoxicological point of view,

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sometimes leading to negative effects on human health [3, 4]. Water plays a fundamental role in most of the physicochemical processes that affect the Earth's crust and is directly involved in the formation of sediments. Indeed, the river is a place of erosion, transit, and then deposition. In addition, at the level of rivers, erosion phenomena, whether chemical or mechanical, predominate. Sediment is therefore a material or fine particles (clay, silt, sand) resulting from this erosion. This means that they are transported in particular thanks to climatic actions (wind, tides, etc.) and/or human actions. They are deposited in waterways, without diagenetic transformation [5, 6]. In recent decades, the contamination of the sedimentary compartment has been the subject of particular attention from the scientific community. Indeed, this compartment is a real trap for many organic and inorganic pollutants of domestic, industrial and agricultural origin, the release of which constitutes a real threat to the environment [7, 8]. Sediment contamination is a major environmental issue because the presence of chemical contaminants is linked to various toxic effects in plants and animals [9]. Exposure to contaminated sediments can have several impacts on the life of living beings, including reproduction, growth, and even other essential biological functions [10]. The water of the Tsiémé River would not have remained on the margins of anthropogenic pollution due to the activities carried out by the waterfront population. For example, agricultural activities (more specifically agriculture), craft activities (carpentry, boilermaking, etc.) and domestic activities (discharges of liquid and/or solid household waste of animal and/or plant origin, etc.). Pollutants from these activities can be found directly (spill) or indirectly (runoff) in the water and can accumulate in sediments, which could cause environmental impacts. Except for the work of Tchoumou et al., [11] on the evaluation of the physico-chemical quality and the suitability for irrigation of the water of the Tsiémé River, no study has been carried out so far on the characterization of the sediments of this river, the general objective of this work is to evaluate the physico-chemical parameters of the sediments of said river in Brazzaville in order to characterize them.

2. Materials and Methods

2.1. Study Area

The Republic of Congo is located in Central Africa, on both sides of the equator. Its surface area is 342,000 km 2 and has a 170 km long coastline. It is bordered to the north by the Central African Republic and Cameroon, to the south by the Democratic Republic of Congo, and finally to the west by the Republic of Gabon.

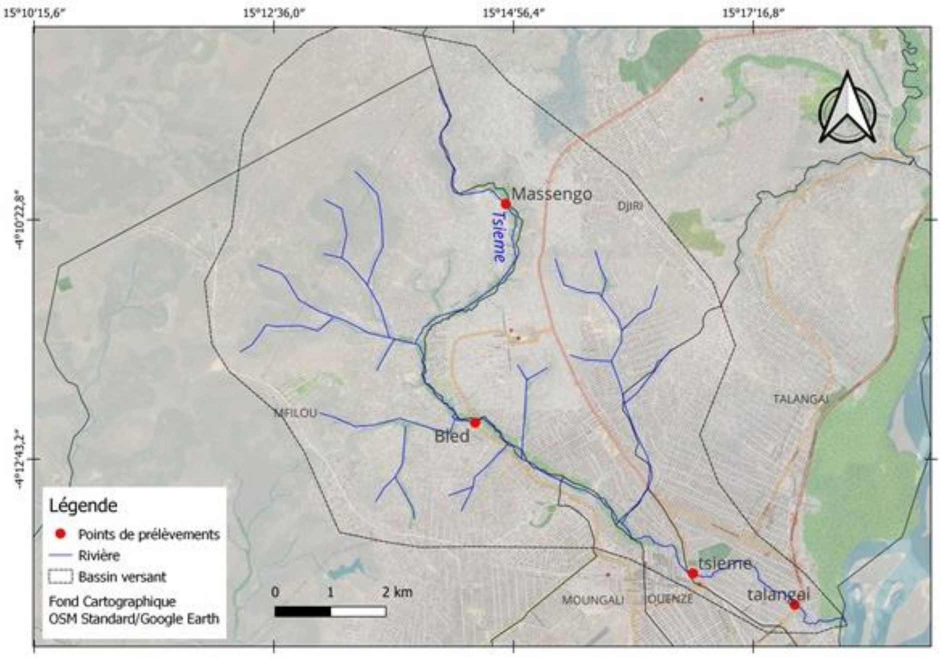

Figure 1. *Status of the study area [11].*

Brazzaville, the political capital, is an agglomeration located on the right bank of the Congo River downstream of the Stanley Pool with an area of 110 km^2 [12]. It is administratively divided into nine (09) districts: Makélékélé, Bacongo, Poto-poto, Moungali, Ouenzé, Talangai, M'filou, Madibou and Djiri [13]. This city has a tropical climate called the << low Congolese climate >>, characterized by abundant rainfall (1.37 m of rainfall / year) and an average temperature of 25 °C. The hydrographic network crossing Brazzaville is entirely included in the Congo River watershed. This river is limited to the north by the Djiri River and to the south by the Tsagamani River [12].

The study was carried out in the Tsiémé River (Figure 1) which crosses four (04) districts of the city of Brazzaville: Djiri (Massengo), Mfilou (Bled), Ouenzé (Tsiemé) and Talangai (Talangai). Figure 1 shows the study area under consideration.

2.2. Sediment Sampling

Two sampling campaigns were carried out in the 2021 dry season and the 2022 rainy season, respectively in August and April in the four (04) districts of the city of Brazzaville. Four (04) samples were taken on the same day according to the selected sampling sites (Massengo, Bled, Tsiémé and Talangaï). At each sampling site, a representative sample of sediment was collected using a plastic shovel at a depth of approximately 5 cm. These samples were stored and transported in the garbage bags. They were then deposited in the laboratory for drying according to the protocols established by Schiavone et al., [14] and UNEP [15].

2.3. Pre-treatment of Sediment Samples

The transported samples were dried for a week at the Laboratory of Applied Mineral Chemistry at the Faculty of Science and Technology of the Marien Ngouabi University. They were then sieved using a 2 mm sieve to get rid of animal debris, plants and stones. These samples were then crushed and sieved using a 53 µm sieve [14, 15]. The powder obtained was used for X-ray diffraction [16].

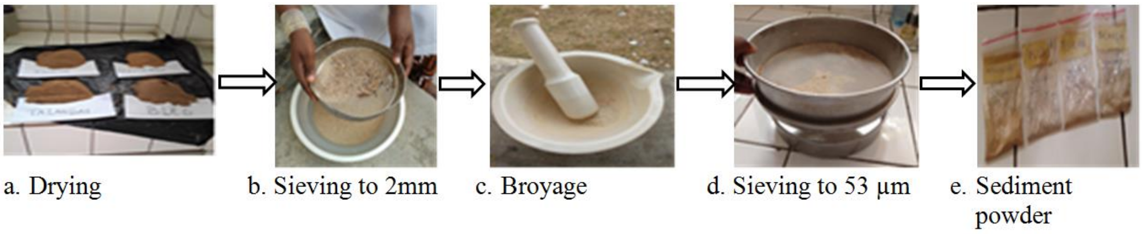

Figure 2. *Sediment sample pre-treatment process.*

2.4. Physico-chemical Analysis Methods

Physicochemical parameters (Temperature, pH, Cond, TDS, water content) were measured in the laboratory of the Plant and Life Chemistry Unit (UC2V). The mineralogy was determined at the University of Cocody in Abidja, Côte d'Ivoire. The particle size was determined at the Institute for Research in Natural and Exact Science (IRSEN) in Pointe-Noire.

Different analytical methods were used to analyze the sediment samples:

1) the potentiometric method was used to determine the electrical conductivity (EC) and the total dissolved salts (TDS) using a Multiparameter Blacklights EZ-9909-SP according to the NF X 31-103 standard;
2) the drying method was used to determine the water content in the oven at 105 °C according to the NF X31-102 standard;
3) the X-ray diffractometry method was used to determine the mineralogy of the sediments using a Bruker D5005 brand powder diffractometer according to the NF EN 13925-1 standard;
4) The Robinson pipette method was used to determine the particle size of the sediments according to the NEN5357 standard.

2.5. Data Processing and Analysis

Two (02) software programs were used for the processing of the analysis results: The Origine software allowed us to draw curves and histograms of the different parameters [17]. In addition, the Qualix software made it possible to trace the diffractogram [18].

3. Results and Discussion

Particle size: The particle size analysis of the samples reveals the different sequential distributions of the particle size curves (Figure 3). Sediment samples during the second sampling campaign show a predominance in descending order of the percentage of particle size fractions. The fraction of coarse sand varies from 57.35 to 93.80%. Followed by fine sands which are between 29.15 and 5.9%, coarse silts between 0.15 and 0.51% and finally fine silts which vary between 0.10 and 0.25% in the four sampling sites.

The variation in the particle size percentages in these different sites could be a function of the geology of the watershed, or either due to erosion phenomena (water and/or aeolian) or to the geography of the environment [19-21]. These results are in agreement with XRD analyses of these same samples.

X-ray Diffraction (XRD): The results of analyses (Figure 4) during the rainy season show the different diffractograms.

Each diffractogram reveals the presence of the different identical peaks, each of which corresponds to 2 theta. The values of 2 theta of the first, second, third, fourth and fifth peak are 21.60 respectively; 26,55; 35,84; 50.12 and 60.03°. These values correspond to the mineral species quartz, which is considered to be the only mineralogical species of these sediments. The abundance of quartz in these sediments shows that it is only surface sediments. This is due to the presence of a large amount of sand and/or coarse elements. According to the literature, the higher the particle size of the samples, the higher the quartz concentrations [22, 23]. The presence of quartz in these different sediment samples could be due to wind input, i.e. erosion of adjacent formations and/or detrital terrigenous fluvial inputs [21]. These results are in agreement with the particle size analyses of the same samples.

Hydrogen Potential (pH): Mean pH values during the dry season range from 5.75 to 6.69 and from 6.38 to 7.13 in the rainy season (Figure 5). These values respect the lower and upper limits set by the WHO (6.5-8.5) during the two seasons. A minimum of 5.75 and a maximum of 6.72 were observed at Massengo and Talangaï. The highest values are obtained in the rainy season. Overall, these sediments have an almost neutral pH except for the Massengo site which has a slightly acidic pH of 5.75. The acidic nature of this point could be explained by the acidic nature of the soil and/or the source rock or by the decomposition of aquatic plants and litter deposited during the rainy season. This could lead to acidifying fertilization during this period of high heat by adding nitrogen in the form of ammonium [24].

Electrical Conductivity (EC): The average EC values observed during the dry and rainy seasons vary from 18 to 173 µs/cm and from 13 to 86 µs/cm respectively (Figure 6). The highest values are obtained in the dry season. Comparing these values with those of conductivity in freshwater environments (100 < EC < 1000 µs/cm), we find a low electrical conductivity of the sediments at the four sampling points [25].

Low electrical conductivity during the rainy season could be due to a phenomenon of leaching of mineral salts from sediments, which could justify the decrease in mineralization [26].

Dissolved Solids Rates (TDS): Figure 7 shows the average values of total dissolved salts. These average values range from 8 to 87 mg/L in the dry season and from 6 to 43 mg/L in the rainy season. The highest values are observed at the Talangaï site in the dry and rainy seasons. In the same direction of evolution as the electrical conductivity, the low values of the total dissolved salts reflect a low mineralization.

Total Organic Matter (MOT): The average values of total organic matter obtained during the dry and rainy seasons vary from 0.248 to 3.549% and from 0.038 to 0.114%, respectively (Figure 8). These values show a maximum at the Talangaï site during the two seasons. The highest values are observed in the dry season. This increase could be due to low water flow, which would cause an accumulation of organic matter in the sediments. Overall, there is a low organic matter content, because according to Meybeck et al., [27], the proportion of organic matter in sediments is described as very high if it reaches 10%. A small amount of organic matter may be caused by oxidation or low release of organic substances [28]. The results obtained are similar to those of the work carried out by Ifo, Moukhchan and Bakary [29-31].

Moisture content (WE): The results of water content analyses during the dry and rainy seasons vary from 6 to 19.3% and 14 to 17.5%, respectively (Figure 9). It should be noted that the maximum values are obtained in the rainy season. They are observed at the Talangaï (19.3%) and Tsiémé (17.5%) sites. In general, low water levels are observed, which could be explained by the phenomenon of runoff. This phenomenon results in the drainage or displacement of coarse particles which would lower the water content [28]. These results are similar to those of the work carried out by Ifo and Bakary [29-31].

Total nitrogen: Observation of the results during the dry and rainy seasons shows that the percentage of total nitrogen ranges from 0.004 to 0.006% and from 0 to 0.005% (Figure 10). These values are highest at the Talangaï site during both seasons. Overall, total nitrogen levels are very low. This decline could be explained by a lack of intense agricultural activity [32]. The results obtained are similar to those of the work of Ifo and Chouti [29-32].

Total Phosphorus: Assay results (Figure 11) show the percentages of total phosphorus during the dry and rainy seasons. These percentages range from 0.007 to 0.07 per cent and 0.06 to 0.1 per cent respectively in the dry and rainy seasons. A minimum (0.07%) is observed at the Tsiémé site during the dry season and a maximum at the Talangai site (0.1%) during the rainy season. It is noted that these values are low during both seasons, which proves that the Tsiémé River receives very little discharge of domestic origin likely to pollute this river with phosphorus.

Table 1. *Different particle size fractions.*

Sampling sites	LF (%)	LG (%)	SF (%)	SG (%)
Talangai	0,22	0,15	26,28	72,56
Tsiémé	0,25	0,51	29,15	69,73
Blèd	0,2	0,25	5,59	93,8

Sampling sites	LF (%)	LG (%)	SF (%)	SG (%)
Massengo	0,2	0,33	41,13	57,35

LF: Fine silt; LG: Coarse silt; SF: Fine sand; SG: Coarse sand

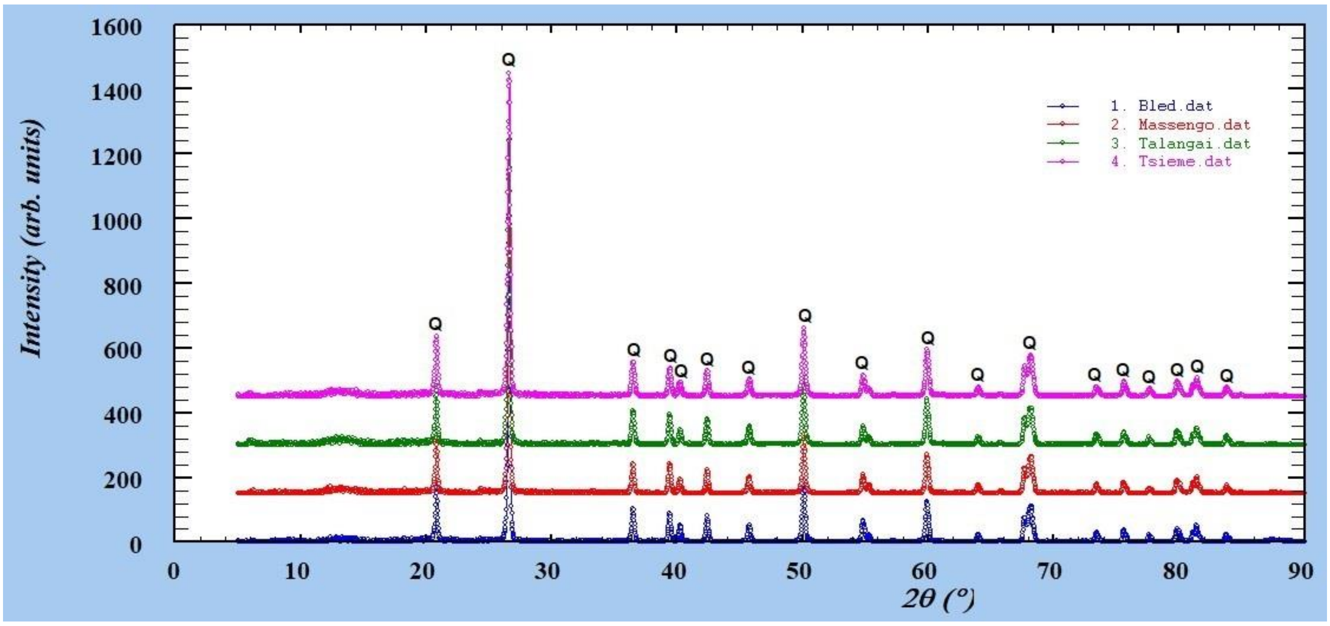

Figure 4. *Sediment diffractograms from different of sampling points.*

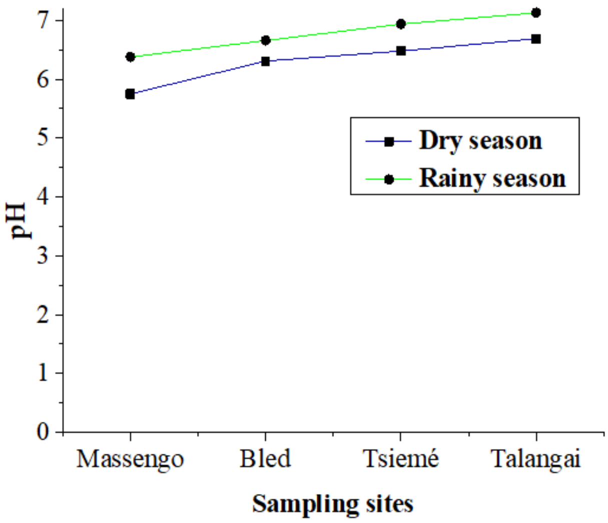

Figure 5. *Variation in pH as a function of sampling sites.*

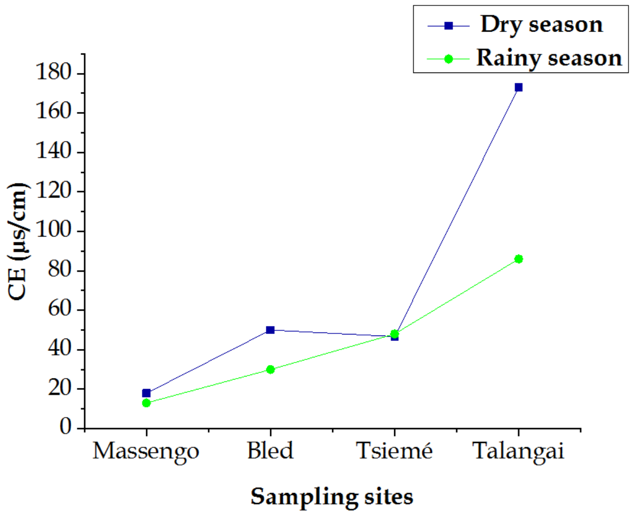

Figure 6. *Variation in EC as a function of sampling site.*

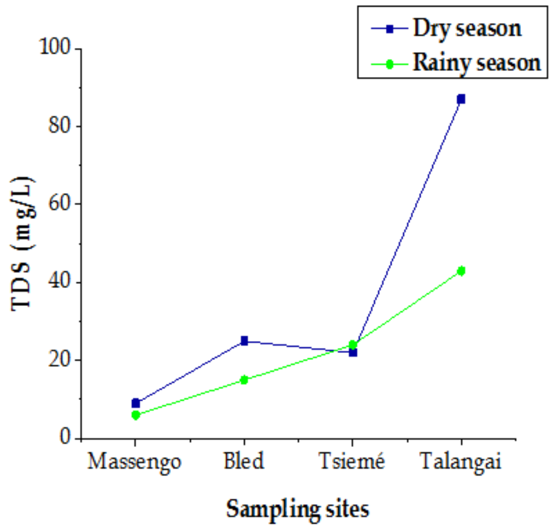

Figure 7*. Variation in the concentration TDS as a function of sampling sites.*

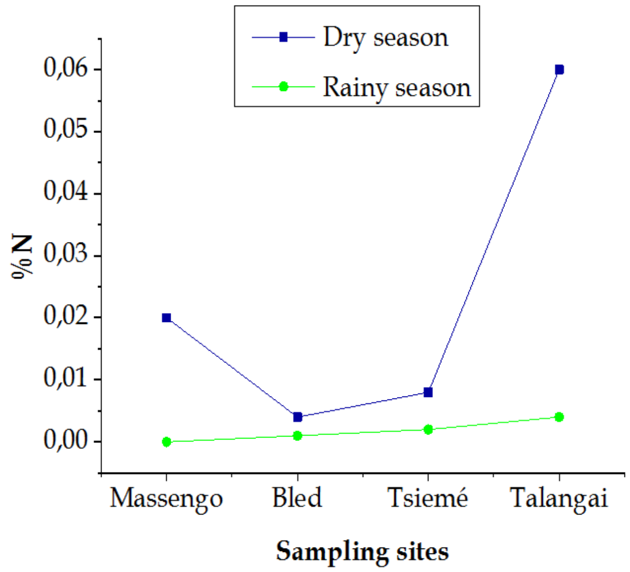

Figure 10*. Change in %N as a function of sampling sites.*

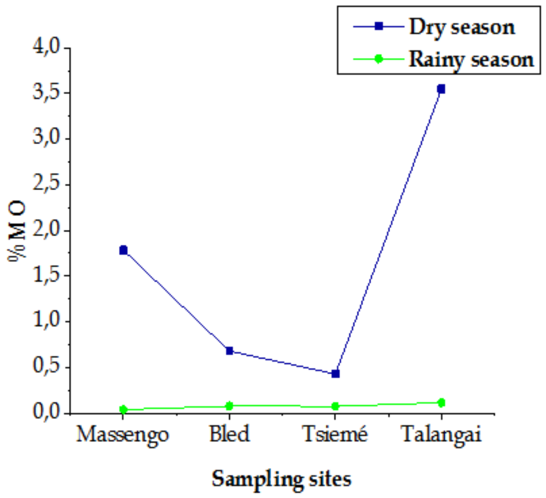

Figure 8*. Variation in %MO as a function of sampling sites.*

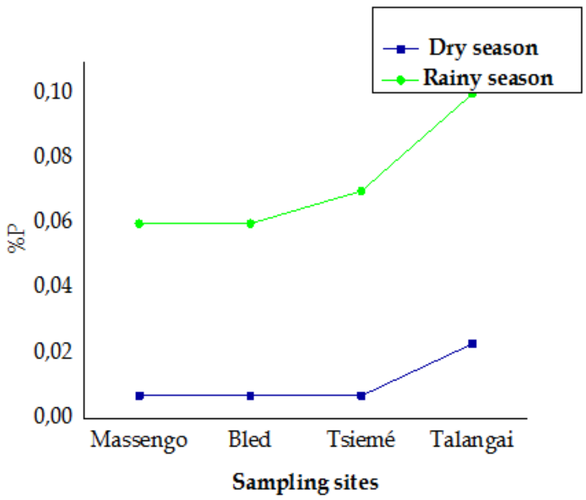

Figure 11*. Variation in % P as a function of sampling sites.*

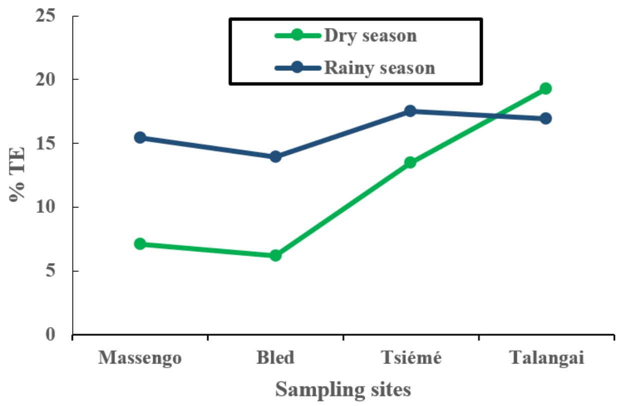

Figure 9*. Change in % TE as a function of sampling sites.*

4. Conclusion

This study made it possible to evaluate the physico-chemical parameters of the sediments of the Tsiémé River in Brazzaville.

The evaluation of the physico-chemical parameters of the sediments of the Tsiémé River shows the presence of quartz as the only mineralogical species found. Also, a heterogeneous particle size composed of coarse sands (57.35-93.80%), fine sands (5.59-29.15%), coarse silts (0.15-0.51%) and fine silt (0.10-0.25%) during the rainy season. The sediments of the Tsiémé River generally have pH values below 7 during both seasons. The low values of EC, total nitrogen, total phosphorus and OM show low mineralization and very low organic pollution. Thus, the sediments of the Tsiémé River do not present any major danger for the moment, despite the discharges of domestic waste observed within the said river. It would be very interesting to determine in our future research the trace metal elements and the speciation of these elements in sediments.

Abbreviations

CE	Electrical Conductivity
TE	Water Tenor
MO	Organic Matter
pH	Hydrogen Potential
TDS	Dissolved Solids Rate
DRX	X-ray Diffraction

Conflicts of Interest

The authors declare no conflicts of interest.

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