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Article

Physicochemical Characteristics of Water and Sediment in Mada River, Nasarawa State, Nigeria

B. W. Tukura [1,] *, C. E. Gimba [2], I. G. Ndukwe [2], B. C. Kim [2]

[1] *Chemistry Department, College of Education, P.M.B 05, Akwanga, Nasarawa State, Nigeria*

[2] *Chemistry Department, Ahmadu Bello University, Zaria, Nigeria*

[3] *Chemistry Department, College of Education, Gindri, Plateau State, Nigeria*

* Author to whom correspondence should be addressed; E-Mail: bitrustukura@yahoo.com.

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Abstract: Surface water resources have played an important role in the development of human civilization. Surface water and sediment samples were collected during dry and rainy seasons for the determination of physicochemical parameters. Parameters were determined using standard methods. Physicochemical characteristics of surface water and sediment varied according to season. Variations according to sites did not adhered to any specific trends. Water pH was slightly acidic (pH = 6.72 ± 0.13) during rainy season and alkaline (pH = 7.74 ± 0.11) in dry season. Temperature (28.80 ± 0.84 ^{o}C), nitrate (0.15 ± 0.01 mg/L), phosphate (15.47 ± 0.17 mg/L) and sulfate (28.43 ± 1.03 mg/L) levels in water increased during rainy season. Sediment pH was more acidic (pH = 6.19 ± 0.18) in dry season compared to rainy season (pH = 6.78 ± 0.08). Organic matter (31.43 ± 4.98 %) and phosphate (60.76 ± 2.60 mg/L) contents of sediment increased during rainy season. Changes in water and sediment chemistry might be responsible for the variations in the physical and chemical properties.

Keywords: physicochemical characteristics; water; sediment; nitrate; phosphate; sulfate.

1. Introduction

About one third of the drinking water requirement of the world is obtained from surface sources like rivers, dams, lakes and canals (Jonnalagada and Mhere, 2001). But, these sources serve as

best sinks for the discharge of domestic as well as industrial wastes (Das and Achary, 2003; Tukura et al., 2009). The geochemical composition of water and sediments is largely governed by the physicochemical characteristics of the depositional environment and associated natural biogeochemical processes such as diagenesis, adsorption/desorption on/from organic matter, and precipitation/ dissolution of Fe/Mn oxyhydroxides (Solai et al., 2010). The regular and periodic changes in the climate synchronized with season are ultimately reflected in the environment parameters also, which in turn have direct or indirect influence over planktonic population (Saravanakumar et al., 2008).

Good water quality resources depends on a large number of physicochemical parameters and the magnitude and source of any pollution load; and to assess that, monitoring of these parameters is essential (Reddi et al., 1993). Assessment of water resource quality of any region is an important aspect of developmental activities of the region, because rivers, lakes and manmade reservoirs are used for water supply to domestic, industrial, agricultural and fish culture (Jackher and Rawat, 2003) Chemical composition of water is a function of hydrogeochemical processes acting in a given environment, thus, monitoring of water quality parameters provide important information for water management (Matthieu et al., 2005; USEPA, 1983). Skilful management of water bodies is required if they are to be used for such diverse purposes as domestic and industrial supply, crops irrigation, transport, recreation, and fisheries (Abel, 1996).

Although a number of authors have studied the physical and chemical properties of some rivers in Nasarawa state (Abiola et al., 2010; Audu et al., 2010; Egharevaba et al., 2010), but information on the seasonal variations of physicochemical parameters of water and sediment from Mada River are limited. The objective of this study is therefore, to determine physicochemical characteristics of Mada River surface water and sediments during dry and rainy seasons. The present baseline information of the physicochemical properties of water and sediment would form a useful tool for further ecological assessment and monitoring of the river quality.

2. Materials and Methods

2.1. Study Area

Mada River is located at latitude 8^{o} 4´ N and longitude 8^{o} 30´ E, and witnesses large influx of wastes both from point and non-point sources, especially during the rainy season. Water flow is perennial. Fishing and irrigation farming takes place along the river. Mada River serves as the major source of water supply to Mada Water Works which provides portable water to the inhabitants of Nasarawa State.

2.2. Sampling

Surface water and sediment samples were simultaneously collected from five sites during rainy and dry seasons into decontaminated plastic containers with caps, at distances of 1 - 10 cm from the bank of the river, according to standard methods (APHA, 1998). The samples were collected in November, January and March which constitute dry season and in May, July and September for the rainy season. Sampling was carried out for two years. Samples were analyzed in triplicates.

2.3. Determination of Physicochemical Parameters

Water pH and temperature were determined *in-situ* in the field, using a calibrated digital pH meter (HI, 99100) and a thermometer, respectively. Conductivity was measured at 25 ^{o}C in µmhos, using a conductivity meter (PT 360 Tronics). Total solids (TS) and suspended solids (SS) were determined using Hach (1998) method. Standard methods (Egharevaba et al., 2010) were used for the determination of total alkalinity and dissolved oxygen (DO). NO_3^- – N and P-PO_4^- were determined by phenoldisulphonic acid (PDA) and Vanodomolybdophosphoric methods, respectively, while Cl^- and SO_4^{2-} were determined by gravimetric methods (Ademoroti, 1996).

3. Results and Discussion

3.1. Water

Physicochemical parameters results for water during the dry and rainy seasons are presented in Tables 1 and 2, respectively. The measured temperature of the water reflected the changes corresponding to the sampling seasons. The surface water temperature varied from 24 to 25 ^{o}C during dry season and 28 to 30 ^{o}C in the rainy season. Mean results indicated that higher temperature (28.80 ± 0.84 ^{o}C) during the rainy season. The water temperature was influenced by the intensity of solar radiation, evaporation and fresh water influx.

Table 1. Physicochemical parameters of surface water during dry season (n = 30)

Site	Temp. (^{o}C)	pH	SS (mg/L)	TDS (mg/L)	EC (µs/cm)	DO (mg/L)	*Alkal.	TOC (mg/L)	NO_3^--N (mg/L)	P-PO_4^- (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)
1	25.00	7.70	4.00	4.00	5.97	2.60	20.00	0.03	0.80	1.37	59.52	24.00
2	25.00	7.80	5.00	4.00	5.96	3.00	20.00	0.05	0.85	1.45	47.67	24.50
3	24.00	7.60	3.00	3.00	4.98	3.20	21.00	0.05	0.90	1.68	43.68	23.15
4	26.00	7.90	5.00	5.00	7.45	3.40	20.00	0.04	0.85	1.50	39.71	25.05
5	25.00	7.70	4.00	4.00	5.97	3.40	20.00	0.05	1.50	1.60	35.73	26.10
Mean	25.00	7.74	4.20	4.00	6.07	3.12	20.2	0.04	0.98	1.52	45.26	24.50
± SD	± 0.71	± 0.11	± 0.84	± 0.71	± 0.88	± 0.34	± 0.45	± 0.01	± 0.29	± 0.12	± 9.13	± 6.11

*Alkalinity (mg $CaCO_3$/L)

Table 2. Physico-chemical parameters of surface water during rainy season (n = 30)

Site	Temp. (°C)	pH	SS (mg/L)	TDS (mg/L)	EC (µs/cm)	DO (mg/L)	*Alkal.	TOC (mg/L)	NO_3^--N (mg/L)	P-PO_4^- (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)
1	28.00	6.60	6.00	3.00	4.48	1.10	11.00	0.14	14.50	15.40	23.83	37.10
2	29.00	6.80	7.00	3.00	4.50	1.20	10.00	0.15	14.80	15.40	19.85	37.25
3	29.00	6.90	8.00	4.00	3.60	1.00	7.00	0.16	15.00	15.77	27.76	36.00
4	30.00	6.60	9.00	3.00	4.48	1.10	10.00	0.15	14.60	15.35	27.76	38.15
5	28.00	6.70	9.00	3.00	4.50	1.00	10.00	0.16	14.65	5.45	27.70	28.65
Mean ± SD	28.80 ± 0.84	6.72 ± 0.13	7.80 ± 1.30	3.20 ± 0.45	4.31 ± 0.40	1.08 ± 0.08	9.67 ± 0.67	0.15 ± 0.01	14.71 ± 0.20	15.47 ± 0.17	25.38 ± 3.53	28.43 ± 1.03

*Alkalinity (mg $CaCO_3$/L)

The pH of the aquatic systems is an important indicator of water quality and the extent of pollution in the studied areas. Unpolluted rivers normally show near neutral or slightly alkaline pH. The pH varied from 7.6 - 7.9 during dry season and 7.3 - 7.5 in the rainy season. Fluctuations in pH values during different season of the year were attributed to factors like removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of river with fresh water, reduction in salinity and temperature, and decomposition of organic matter (Rajasegar, 2003). Mean water pH values during dry (7.74 ± 0.11) and rainy (6.72 ± 0.13) seasons were above the maximum permissible limit (pH = 6.5) (WHO, 2004).

Dissolved oxygen (DO) ranged from 2.6 - 3.4 mg/L in dry season and 1.00 - 1.20 mg/L during the rainy season. The depletion in DO levels during rainy season (1.08 ± 0.08 mg/L) indicated that deoxygenation rate due to biological decomposition of OM is higher than the reoxygenation from atmosphere (Das and Achary, 2003).

Conductance qualitatively reflects the status of inorganic pollution and is a measure of total dissolved solid and ionized species in the water. Electrical conductivity (EC) varied from 4.98 - 7.46 µs/cm in dry season and 3.60 - 4.53 µs/cm in rainyseason. The low mean EC value (4.1 ± 0.40 µs/cm) recorded during rainy season might be due water dilution, while the higher EC recorded in dry season may be attributed to reduced water volume and high rate of evaporation.

The suspended solid (SS) ranged from 3 - 5 mg/L in dry season and 6 - 9 mg/L during the rainy season. Total dissolved solid (TDS) values were observed to have decreased during rainy season. High levels of dissolved and suspended solids in the water systems increase the biological and chemical oxygen demand, which deplete the dissolve oxygen level in the aquatic system. The levels of TDS in a broad sense reflect the burden of aquatic systems. The suspended solid levels were higher during the rainy season (7.80 ± 1.30 mg/L). Increased discharge of solid waste into the river during rainy season

may account for the increase in SS levels. Water dilution due to increase volume of water from rains could have been responsible for the depletion (3.20 ± 0.45 mg/L) in TDS level. TDS concentrations were below the WHO (2004) maximum allowable limit of 500 mg/L.

Alkalinity values did not show any spatial change during the dry season but indicated temporal (season) change. Low alkalinity levels were recorded in rainy season, ranged from 7 – 11 mg $CaCO_3$/L.

Distribution of nutrient is mainly based on a season. Fresh water flow from farm land showed both spatial and temporal variation. The nitrogen values ranged from 0.80 to 0.90 mg/L in dry season and 14.50 to 15.00 mg/L during the rainy season. The nitrogen is usually derived from anthropogenic sources like agricultural fields and domestic sewage containing nitrogenous compounds which increased during rainy season due to rainfall. Low level of NO_3^--N during dry season might be due to utilization by phytoplanktons.

TOC content ranged from 0.03 – 0.05 mg/L during dry season and 0.14 – 0.16 mg/L in the rainy, but decreased (0.04 ± 0.01 mg/L) during the dry season. PO_4^{3-}-P varied from 1.37 to 1.60 mg/L in dry season and 15.40 to 15.77 mg/L during the rainy season. Higher concentration of inorganic phosphate (15.47 ± 0.17 mg/L) observed during the rainy season might be an intrusion from land into the river. Chloride is present in nearly all natural water with varying concentration, depending on the geochemical condition of the area. Concentration of chloride above 250 mg/L can impact distinct salty taste (Das and Achary, 2003). The highest and lowest chloride concentrations were recorded at site 1 (59.57 mg/L), and 35.73 mg/L at site 5 in dry season, while during the rainy season chloride levels ranged from 23.83 to 29.85 mg/L. Chloride exhibited wide and high concentration range. This may be attributed to anthropogenic origin. The decrease in water chloride level (25.38 ± 3.53 mg/L) during the rainy season might be as a result of increased volume and subsequently dilution of water body from rainfall.

Water sulfate varied from 23.15 to 26.10 mg/L in dry season and 36.00 to 38.65 mg/L during the rainy season. Increase in water sulfate contents (28.43 ± 1.03 mg/L) during the rainy season may be attributed to increase in influx of sulfate from sulfate fertilizers from farm lands.

3.2. Sediment

Sediment physicochemical properties results are presented in Tables 3 and 4. The pH varied according to sites and seasons. During the dry season (Table 3), sediment pH was acidic and varied between 6.10 and 6.50. Organic matter (OM) contents also varied according to sites. The highest and lowest OM contents were recorded at sites 2 (19.15) and 3 (14.15), respectively. Highest level of alkalinity was obtained at site 3 (30.20 mg $CaCO_3$/L) and the lowest at site 5 (25.00 mg $CaCO_3$/L).

Nitrate concentrations ranged between 1.45 and 1.95 mg/L. Site 5 recorded the highest phosphorus contents (64.40 mg/L) and the lowest value at site 3 (57.90 mg/L).

Table 3. Physicochemical properties of sediment during dry season (n = 30)

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Mean ± SD
pH	6.50	6.05	6.20	6.10	6.10	6.19 ± 0.18
Organic matter (%)	16.00	19.10	14.15	18.10	17.02	16.87 ± 1.91
Alkalinity (mg $CaCO_3$/L)	29.05	26.10	30.20	27.05	25.00	27.48 ± 2.13
NO_3^--N (mg/kg)	1.83	1.95	1.45	1.89	1.76	1.78 ± 0.20
PO_4^{3-}-P (mg/kg)	62.30	59.10	57.90	60.10	64.40	60.76 ± 2.60

Table 4. Physicochemical parameters of sediments during rainy season (n = 30)

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Mean ± SD
pH	6.80	6.70	6.80	6.90	6.71	6.78 ± 0.08
Organic matter (%)	30.05	26.05	28.02	38.05	35.00	31.43 ± 4.98
Alkalinity (mg $CaCO_3$/L)	19.00	17.10	20.00	18.25	17.07	18.28 ± 1.26
NO_3^--N (mg/kg)	1.92	2.05	1.60	1.97	1.85	1.88 ± 0.18
PO_4^{3-}-P (mg/kg)	68.20	66.30	59.15	66.10	67.70	65.49 ± 3.66

Results for rainy season (Table 4) indicated that sediment pH was slightly acidic with the highest and lowest values recorded at site 4 (6.90) and site 2 (6.70), respectively. OM contents ranged between 28.10 and 38.05 mg/L. Alkalinity was highest at site 3 (20.00 ± 4.05) ant lowest value at site 2 (17.10). Nitrate levels varied from 1.60 to 2.05 mg/L. Phosphate concentration was highest at site 1 (68.20 mg/L) and the lowest at site 4 (6.10 mg/L).

Physicochemical properties of sediment were generally higher during the rainy season. At low pH, hydrogen ion competes with metal cations adsorbed onto sediment surface leading to their remobilization into the water column. The relatively low value of pH (6.19 ± 0.18) during the dry season could be as a result of the oxidation of FeS to H_2SO_4 (Ramanathan, 1997). Variations in pH might also be attributed to redox changes in sediments and water column apart from the influence of fresh water (Holmer et al., 1994).

Organic matter in river sediment is derived from primary production within aquatic ecosystems (autochthonous sources) and also from terrestrial biota (allochthoous sources) by transport of leached and eroded material into the river. Increased in OM content (31.43 ± 4.98 %) during the rainy season may be due to the nature of the sediment and high rate of sedimentation and decomposition of foliage and other vegetative remains in the sediment (Saravanakumar et al., 2008).

Nitrate contents were higher (1.88 ± 0.18 mg/L) during the rainy season due to the oxidation of dead plant organic matter which settled on top layer. The low nitrate levels observed during the dry season may be ascribed to the low level of organic matter along the river. Higher values of phosphates (65.49 ± 3.66 mg/L) were recorded during the rainy season and low during the dry season. The high values observed may be due to dead organic matter from top layer and the low values may be related to removal of top layer of sediments by heavy floods. Discharge and subsequent sedimentation of suspended particulates from phosphate and nitrogen fertilizers, and domestic wastes discharged into the river as a result of rainfall might have also contributed to the increase in sediment phosphate contents. Results in this study were consistent with those reported by (Tukura et al., 2005) and (Ekeanyanwu et al., 2010).

4. Conclusion

Physicochemical characteristics of surface water and sediment varied according to season. Variations according to sites did not adhered to any specific trends. Physicochemical properties of water significantly increased during the dry season, except for nitrates, phosphates and sulfates. Sediment pH, OM and phosphate contents increased during the rainy season.

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