African Journal of Pure & Applied Sciences

ISSN: 2710-0758
DOI 10.33886/ajpas.v4i1.376
Journal homepage: http://journal.ku.ac.ke/index.php/AJPAS

Research Article Open Access

Water Quality Assessment and Spatial Variation in Aba River Water, South-Eastern Nigeria

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Received 8th January, 2023/ Accepted 3rd May, 2023, Published online: 30th June 2023

How to cite:
Wokeh, O., Okey-Wokeh, C., & Orose, E. (2023). Water Quality Assessment and Spatial Variation in Aba River Water, South-Eastern Nigeria. *African Journal of Pure and Applied Sciences,* 4(1), 36-41. https://doi.org/10.33886/ajpas.v4i1.376

ABSTRACT

The status of the Aba freshwater ecosystem (river) was assessed for the influence of human activities at different sections of the river and its attendant effects on water parameters. To achieve this, samples of water were collected monthly from January to June 2020 at three sampling stations marked A_1, A_2, and A_3 and were analysed on-site for water, electrical conductivity (EC), dissolved oxygen (DO), pH, salinity, total dissolved solids (TDS) and temperature with the aid of a handheld multi-parameter kit. Biochemical oxygen demand (BOD) was fixed on-site and taken to the laboratory along with samples for potentially toxic metals (PTMs), Cd, Cu, Pb, Fe, and Zn),which were analysed by standard analytical procedure. Statistical variation across the sampling hotspots was determined with a one-way analysis of variance. The results indicated the average values of pH were moderately low in all the stations with little statistically variation ($p > 0.05$) between samples. The mean EC indicated station A_1 (1394.32±152) had the highest concentration, followed by station A_2 (972.14±52.22), and A_3 (496.16±72.10) was the lowest. The mean salinity, TDS and Cl^- followed a similar pattern as EC, with significant differences ($p < 0.05$) in all the stations. DO values for A_3 (4.90±0.37) were the highest while for A_1 (3.34±0.21) they were the least. The mean BOD results for station A_1 (6.54±5.54) were the highest whereas for A_3 (3.28±0.66) they were the lowest. The value of metals across the stations indicated higher occurrence pattern: Fe> Zn >Cu> Cd> Cr> Pb. Generally, the concentrations of physicochemical and potentially toxic metal parameters were above the threshold for surface water and this deduced that the river was contaminated and needed urgent remediation. Also, the government should regulate the discharges of industrial effluents, agricultural wastes and sewage into the water body to safeguard the river from further deterioration.

Keywords: Acidosis; Anthropogenic impact; Contamination; Ecosystem; Remediation.

INTRODUCTION

Water is considered as one of the most pivotal natural resources sought after by humans for domestic use and economic development (Ankomal-Baffoe *et al* 2021). Hardly is there any human endeavour where water is not required, and this can principally be sourced from rivers, streams, lakes, and ground waters (Okey-Wokeh *et al* 2021). Rivers stand as a prominent source of water in many parts of the world, particularly developing nations like Nigeria, and one river of such value in south-eastern Nigeria is the Aba river.

The Aba river ecosystem is a key source of livelihood for the densely populated Aba communities in South-east Nigeria. It provides water for drinking, bathing, washing and irrigation for the people of Emologor, Umuobo, Ogbor, Umuola, and a host of other communities residing close to the river who do not have access to potable water (Udo and Elendu 2019). Outside these functions, this water body also serves as a breeding ground for fish, and a home for amphibians, reptiles, mammals and other aquatic animals, thereby sustaining the ecological balance between the aquatic and terrestrial ecosystems (Echude *et al* 2022). Conversely, with advent of urbanization and industrialization and its resultant higher concentration of human population in most cities, much pressure has been placed on the environment (Okey-Wokeh and Wokeh 2022; Fubara *et al* 2022). The impacts of these pressures are enormous, ranging from climate change with its effects such as rise in temperature, increased rainfall, flooding and change in hydrological dynamics (Ankomal-Baffoe *et al* 2021). There are reports of aquatic pollution been endemic in most developing nations of Africa and Asia with no or poor environmental sustainability plan. As a result, aquatic ecosystems like rivers, streams and lakes have become discharge points of untreated industrial and commercially wastes (Kassegne *et al* 2018).

The excess load of contaminants into the river systems in the recent times has become a major concern in many parts of the world, particularly in Niger delta region of Nigeria. This region is reportedly being the fastest region in sub-saharan Africa with ecological change, and deterioration of the aquatic environment, due to crude oil exploration, siltation and coastal erosion (Olomuokoro and Abdul-Rahman 2011). The Aba river located in an area known as beehive of industrial and commercial activities is not an exception.

The study was therefore, necessitated by the unabated expansion of commercial and industrial activities around the Aba water course, and the aim was to gauge the levels of deterioration on the water status by comparing the physicochemical and PTM concentrations of the river water with the World Health Organization threshold for surface water. The findings will provide reference data for academics, water managers, and policy formulators

Description of Study Area

The Aba river is a tributary of the Imo river located in Aba, a commercial city in south-eastern part of Nigeria. The river flows from the Ngwa rural territories of Aba down to Opobo and empties alongside its creeks into the Atlantic Ocean through Ikot Abasi (Figure 1). Aba is known for her beehives of commercial and industrial activities. It is situated between longitude 7°15-7°14 E and latitude 5°05-5°30N. With the aid of a global positioning system (GPS), three sampling stations were marked (A_1, A_2, and A_3), each station being 200 metres away from the others. The sampling stations were chosen on the basis of the different anthropogenic activities around the water course.

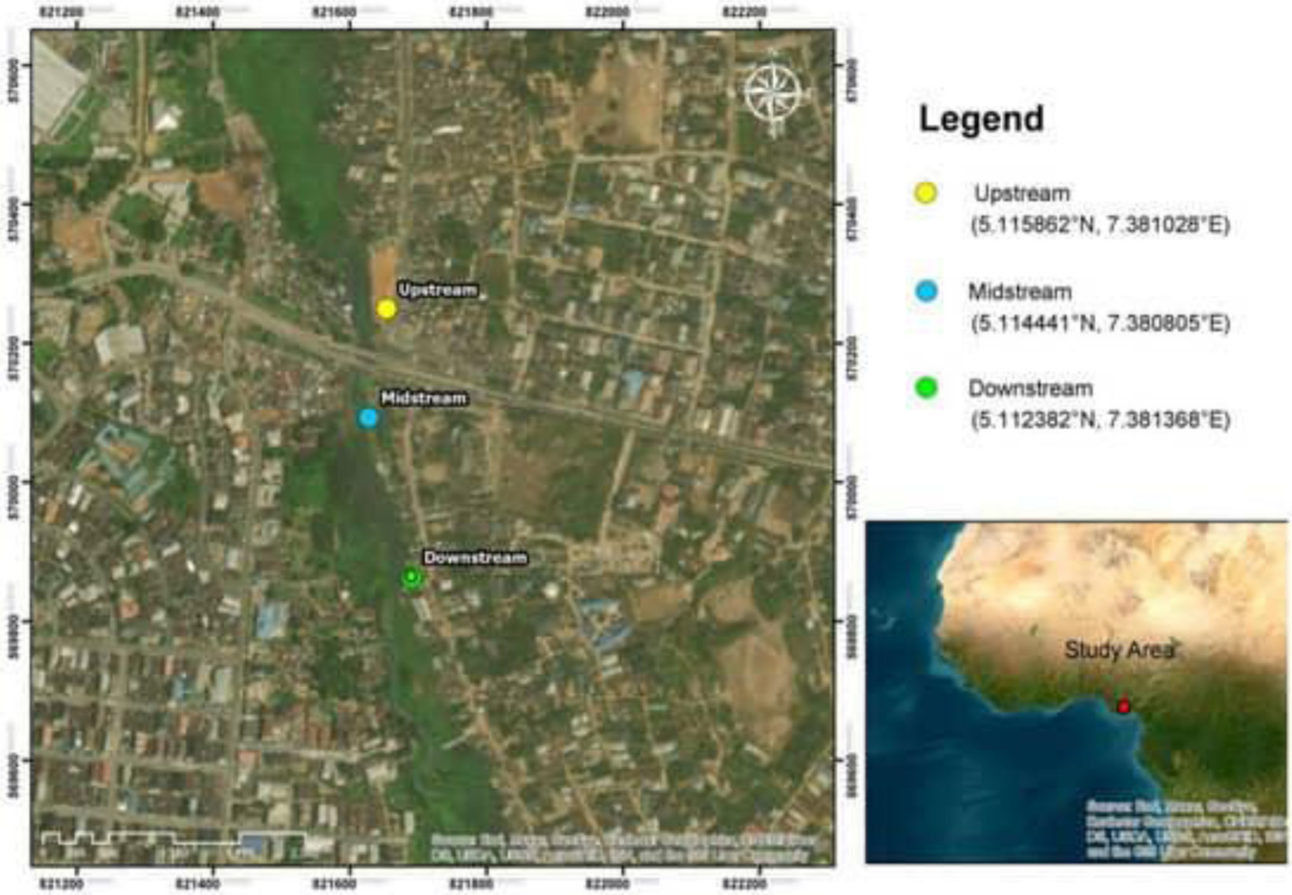

Figure 1: Map of the study area showing the three sample points.

METHODOLOGY

Sample collection and analysis

Water samples for the analysis of physicochemical parameters and PMTs were collected from the three sampling stations monthly (January-June 2020) with glass vial which were sterilized and rinsed before used. The water samples collected were analysed on-site for water pH, EC, TDS, and salinity using Hanna portable conductivity metre while temperature and DO were measured with the aid of the instrument described by Okey-Wokeh *et al.* (2021). Water samples were determined for BOD analysis was fixed on-site and taken to the laboratory alongside samples collected for chloride, water hardness and the PMTs Cd, Cu, Cr, Fe, Pb and Zn using the standard analytical procedures described by APHA (2001).

QUALITY CONTROL AND ASSURANCE

The proper quality assurance measures and practices were implemented during this study. All through the research, deionized water was used and all of the reagents were of analytical grade, while the glassware was well cleaned. Repeated analyses of the samples were performed against spectrochemical grade BDH reference metal solutions that were globally recognized in order to assure accurate instrument reading and accuracy of the analytical technique.

Statistical analysis

Statistical variation across the sampling stations was determined using a one-way analysis of variance with the aid of Microsoft excel and SPSS.

RESULTS AND DISCUSSION

Table 1 presents the mean results of spatial variations on physicochemical and PMT parameters across the three sampling stations for a period of six months. The mean concentrations of the physicochemical and metal parameters were compared with the World Health Organisation (WHO) threshold for these metals in surface water.

Parameters	Station (A_1)	Station (A_2)	Station (A_3)	WHO limit
pH (mg/L)	6.08 ± 0.24^{a}	6.44 ± 0.63^{a}	6.72 ± 0.53^{a}	6.50-8.50
EC (µScm^{-1})	1394.32 ± 152.08^{c}	972.14 ± 52.22^{b}	496.16 ± 72.1^{a}	1000
Temperature (ºC)	28.80 ± 0.30^{a}	25.97 ± 0.38^{b}	24.65 ± 0.47^{c}	< 40
TDS (mg/L)	580.40 ± 82.40^{c}	370.19 ± 38.89^{b}	265.03 ± 39.72^{a}	500
Salinity (mg/L)	21.42 ± 1.27^{c}	13.44 ± 4.42^{b}	8.60 ± 1.49^{a}	1000
DO (mg/L)	3.34 ± 0.29^{a}	4.48 ± 0.34^{b}	4.90 ± 0.37^{c}	5.00
Cl- (mg/L)	7.42 ± 0.68^{c}	5.45 ± 1.17^{b}	2.84 ± 0.58^{a}	100
BOD (mg/L)	6.54 ± 5.54^{b}	4.10 ± 0.82^{ab}	3.28 ± 0.66^{a}	2-5.0
Total Hardness (mg/L)	38.87 ± 9.54^{b}	45.70 ± 9.20^{b}	22.47 ± 3.31^{a}	500
Cd (mg/L)	0.50 ± 0.32^{ab}	0.46 ± 0.24^{ab}	0.052 ± 0.01^{a}	0.003
Cu (mg/L)	0.63 ± 0.47^{b}	0.49 ± 0.26^{ab}	0.06 ± 0.02^{a}	2
Pb (mg/L)	0.048 ± 0.03^{a}	0.039 ± 0.07^{a}	0.034 ± 0.01^{a}	0.01
Cr (mg/L)	0.057 ± 0.06^{b}	0.059 ± 0.02^{b}	0.033 ± 0.004^{a}	0.05
Fe (mg/L)	2.69 ± 0.17^{b}	2.24 ± 0.21^{ab}	1.87 ± 0.14^{a}	0.3
Zn (mg/L)	0.94 ± 0.22^{a}	0.63 ± 0.15^{a}	0.42 ± 0.32^{a}	3.0

a, b, c: Means with different superscripts in the same column are significantly different ($p < 0.05$)

The physicochemical and potentially toxic metal properties, such as pH, EC, TDS, salinity, temperature, DO, BOD, Cl^-, total hardness, Cd, Cu, Cr, Fe, and Zn concentrations, were recorded at the three stations (A_1, A_2, and A_3) shown in (Figure 1).

The mean pH concentration of water samples collected at the stations was highest for station A_3 (6.72±0.53), followed by A_2 (6.44±0.63) while the least mean was observed for station A_1 (6.08±0.24). The pH values fell below 6.5-8.5 recommended by (WHO 2017) as standard for domestic water use except for station A_3. In terms of spatial mean pH, the result showed no spatial variation ($p < 0.05$) in all the sampling locations. The values of water pH obtained indicated that the water is generally acidic, which is consistent with the previous observation by Adesuyi *et al.* (2015) in Nwaja creek, although the pH values at this river were below 8.21-8.68 recorded by (Fubara *et al* 2022) in Orashi river. Water with a pH value below 6.5 mg/L is adjudged unhealthy for human consumption because of the risk of acidosis and the stimulating effects on PMT concentrations in water (Adesakin *et al* 2020). The acidic nature observed in Aba surface water could be attributed to the discharges of industrial effluents, abattoirs, and other organic wastes into the water body.

The mean EC indicated that station A_1 (1394.32 ± 152.08 µS/cm) recorded the highest concentration, and the lowest mean was observed in A_3 (496.16±72.10 µS/cm). These values were indicative of spatial variations ($p < 0.05$). The EC concentration observed in station A_1 was above the (WHO 2017) standard for freshwater compared with A_2 and A_3, which were within the threshold. The elevated conductivity values observed in this study show the river receives higher discharges of inorganic salts in ionized form from the surrounding environment (Okey-Wokeh *et al* 2021), which was in consonance with the values recorded by (Arafat *et al* 2021) in the urban river. The mean conductivity observed in the water samples collected might likely affect the water taste, thereby making it unfit for consumption and agricultural uses.

The mean river water temperatures were highest for station A_1 (28.80±0.30), followed by station A_2 (25.97±0.38) and lowest for station A_3 (24.65 ± 0.47). The values of water temperature showed spatial variation ($p < 0.05$) although the values observed across sample stations were within the stipulated threshold given in the WHO water quality guidelines (WHO 2017). The higher temperature recorded in A_1 was as a result of impacts of anthropogenic disturbance on the river, which may have also affected the DO levels in the sample stations.

The average TDS and salinity follows a similar trend as EC with the TDS mean concentration in the station A_1 being above the WHO permissible limit compared to other stations A_2 and A_3. The salinity values indicated that the river was a freshwater ecosystem. The TDS mean concentrations presented in Table 1 revealed the values were elevated, which could be attributed to the effects of industrial discharges, agricultural runoff, and car wash wastes (Amah-Jerry *et al*; 2017). The results obtained from this study indicated there was a relationship between TDS, salinity, and EC. The increase in TDS and salinity results in an increase in conductivity, contrary to the assertion that increases in TDS bring decreases in EC (Arafat *et al*; 2021).

The results presented in Table 1 indicated that the mean DO increased progressively from stations A_1 (3.34 ± 0.21), A_2 (4.48 ±0.34), and A_3 (4.90 ± 0.37), with spatial variation ($p < 0.05$) across the stations. The values were generally below the 5.0-8.5 mg/L DO standard recommended for surface /drinking water and aquatic life (WHO 2017). The mean concentration of DO observed from the water samples collected from the Aba river were in consonance with the values reported by Butu *et al.* (2022) in Rido river, observed to be polluted. The survival of aquatic life is dependent on the DO level (Fubara *et al* 2022). The DO concentrations found in this water body portend danger for fish and other organisms (Tamrakar *et al* 2022). In contrast, the mean BOD showed a decrease in concentration moving from station A_1 (6.54 ±5.54), being the highest, down to A_3 (3.28 ± 0.66), which had the lowest. The results showed spatial variation ($p < 0.05$) between stations A_1 and A_3, but A_2 was not spatially different ($p < 0.05$) from other stations. The values of BOD observed across the sample stations were higher than the threshold. Previously, Amah-Jerry *et al.* (2017) and Okey-Wokeh *et al.* (2021) reported similar BOD values in Aba and Ogbor rivers respectively. The elevated BOD concentrations observed in the present study was attributed to discharges of Abattoir wastes, industrial wastewater, sewage and other organic wastes, which may have affected the DO concentrations in this aquatic environment (Aniyikaiya *et al* 2019). The consumption of water with these BOD levels is capable of causing water-related diseases.

The mean concentration of Cl^- showed a gradual decrease from station A_1 (7.42 ± 0.68), being the highest, to A_3 (2.84±0.58), which had the lowest. There was spatial variation ($p< 0.05$) in all the sampling locations. As for total hardness (TH), the result fluctuated from A_1 (38.87±9.54), then increased at A_2 (45.70 ± 9.20), and later lowered in A_3 (22.47±3.31). The values of A_1 and A_2 showed no spatial variation from each other but were significantly different from A_3. The findings revealed the river water was a soft water based on the total hardness values.

Variability in potentially toxic metal levels

The mean values of PMT across the stations were the highest for Cd in station A_1 (0.50 ± 0.32) compared with station A_3 (0.05 ±0.01), which had the least value with a significant difference ($p < 0.05$). Significantly, the mean concentration of Cu observed between stations A_1 (0.63 ± 0.47) and A_3 (0.06 ±0.02) differ greatly and the highest mean was recorded in A_1, followed by A_2 while A_3 had the least. The Pb values revealed no spatial variation ($p <0.05$), with the highest mean value being observed in A_1, while A_3 (0.034 ±0.01) had the lowest value. Similarly, the mean Zn values followed the same trend as Pb. Generally, the mean distribution of metals in this study showed a higher occurrence pattern: Fe <Zn < Cd < Cr < Pb. The values of Fe, Cr, Cd, and Pb were significantly above the World Health Organisation's permissible limit 0.3, 0.05 and 0.003 mg/L respectively for drinking water and aquatic life.

Pb and Cd are non- essential elements and their abundance in water portends serious danger for humans and aquatic organisms (Okey-Wokeh and Wokeh 2022). The increased concentration levels of Pb in this study could be due to rising anthropogenic impacts on surface water with similar results having been previously reported by Onojake *et al.* (2015) and Okey-Wokeh *et al.* (2023) in the rivers. The elevated mean concentrations of Pb obtained in the current study have the capacity to raise the blood pressure and cause anaemia in humans when water contaminated with Pb is consumed (Adesiyan *et al* 2018). The elevated levels of Cd observed in this surface water may have resulted from household garbage and emissions from industries that are closely located to the aquatic environment. Cadmium is a non-essential element and when it accumulates in human organs through water consumed, can cause renal and liver cancer (Rahimzadeh *et al* 2017).

Naturally, Fe is abundant on the earth and is an essential component of the living organisms (Okey-Wokeh and Wokeh 2022). Despite its abundance Fe is often a growth limiting factor in the environment due to the fact that in contact with oxygen, Fe forms oxides, which are highly insoluble and thus is not readily available for uptake by organisms (Abbaspour *et al* 2014). This results in elevated concentration of Fe in surface water and other media (Davies and Oghenetekevwe 2022). The abundance of Fe in this water body could be due to industrial, dredging, mechanic and other array of anthropogenic activities prominent around station $A_{1,}$ which decreases to downstream station A_3. When water with elevated Fe concentration beyond the limit recommended by the regulatory agencies is consumed, it is capable of causing health impairments such as nervous system disorders, liver cancer, cirrhosis and infertility in some cases (Kumar *et al.*, 2017). In contrast, the mean concentrations of Zn across the stations were within 3 mg/L recommended for surface water by WHO (2017). This could be due to the low Zn content in the swept-out effluents along the sampling stations. Similar results of low Zn concentration was previously reported by Okey-Wokeh and Wokeh (2022) in Mini-Ezi stream.

CONCLUSION

The study has examined spatial variations of the Aba river water and assessed the extent of deterioration in water quality across the sample stations. The results of physicochemical and PMT levels were found to have fallen short of the WHO standard for surface water and drinking water. The effects of deteriorating water quality on aquatic life have also been appraised. Water parameters examined were: pH, EC, TDS, DO, BOD, Cd, Pb, Fe, and Cr. The findings revealed that station A_1 had elevated concentrations of physicochemical and metal parameters than A_2 and A_3, due to intense anthropogenic disturbances in the area. The water quality of the Aba river was generally low and unfit for human consumption. It is recommended that the river water be always treated before use, while the government speeds up remediation plans of the river to avoid waterborne diseases within the communities that depend on this river as a source of drinking water and other means of livelihood. Also, to keep the Aba river water quality high, there should be reduction of agrochemicals leaching and runoff of industrial effluents to this river.

ACKNOWLEGEMENT

The authors wish to appreciate Godspower Eze for his assistance during the sampling period.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare

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