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EVALUATION OF HEAVY METAL CONCENTRATION IN BODY FLUID OF THE INHABITANTS LIVING ALONG ABA RIVER, ABIA STATE, NIGERIA

*[1]A. I. ALI, [2]T. Y. RILWANU, [3]E. D. ANYANWU, [4]A. I. TANKO AND [5].B. M, BASHIR

[1,2,4] Department of Geography, Bayero University, Kano, Nigeria
[3]Department of Zoology and Environmental Biology, Michael Okpara University of Agriculture, Umudike, Nigeria
[5]Department of Geography, Gombe State University
***Corresponding Author:** alinaira.71@gmail.com **Tel:** 08054813859

ABSTRACT

River pollution and its health effects has been one of the main issues in urban water management in Nigeria and globally due to the ever increasing population and developmental activities. Aba River is being polluted by a number of domestic, industrial and commercial activities. The aim of the study was to evaluate the concentrations of some heavy metals in body fluids of the inhabitants living along Aba River, Abia State, Nigeria, using water and blood samples. Water samples were collected from locations along the river within the six selected communities. The communities were purposely targeted for medical outreach. Convenience sampling was used to select people for blood samples test. Water and blood samples collected were analysed in the laboratory for heavy metals. The water results were compared with national standards. Two-way ANOVA and Pearson correlation co-efficient were used to determine significant differences among the communities and seasons, relationships between metals in water and metals in blood. The results identified 8 heavy metals of varying concentrations in the water and blood samples collected. The dominant metals were: Zinc, Manganese, Iron and Lead recorded in higher concentrations in water in the downstream stations and dry season as well as in blood samples in the communities. Some of the heavy metals in water exceeded acceptable limits while the blood levels though high, were still within cut off levels. High levels of Zn, Mn, Fe and Pb recorded in the bloods portends potential public health risk. A drastic action must be taken to stem the trend.

Keyword: Blood, Diseases, Heavy Metals, Permissible Limit, Population, Water

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INTRODUCTION

Water quality has become a major challenge in the world today; as it is being polluted by industrial and urban wastes generated largely by human activities (Ojutiku and Okojevoh, 2017). The main anthropogenic sources of heavy metals contamination of water, sediment and aquatic animals are industrial activities, mining, agriculture and disposal of untreated and partially treated effluents containing toxic metals (Huang *et al.*, 2020; Desiree *et al.*, 2021; Anyanwu *et al.*, 2022a and b). Heavy metal contamination has become a global problem due to inherent bioaccumulation and biomagnification potentials and their long-term persistence in environmental compartments (Wang *et al.*, 2014; Dhar *et al.*, 2020 Gao *et al.*, 2020; Zeng *et al.*, 2020) warrants constant monitoring. Heavy metal contamination of rivers (like Aba River) flowing through cities is a major problem in the developing countries (Maigari *et al.*, 2016; Amah-Jerry *et al.*, 2017). Heavy metals were found in body fluids of inhabitants living along the river channels and using the water for various purposes (Gupta *et al.*, 2022). Body fluids are liquids within the human body, that help transport nutrients or expel waste from cells (New Health Guide, 2016) and the most common is the blood. Due to uncontrolled pollution levels driven by causative factors like industrial growth and heavy increase in traffic using petroleum fuels (Egbuonu *et al.*,2018), the blood system of most inhabitants living along or using water from heavily polluted rivers are contaminated (Nouri, *et al.*, 2008; Gupta *et al.*, 2022).

Aba River is the main source of water for the residents and the numerous industries and commercial establishments in the Aba metropolis. The river has been consistently and extensively used for drinking, laundering, bathing, swimming, livestock watering and irrigation, especially during the dry season. With wastes from industries and commercial establishments being discharged into the river, the water quality has deteriorated drastically. (Amadi, 2012; Amah-Jerry *et al.* 2017; Nwankwoala and Ekpewerechi 2017; Egbuonu *et al.*, 2018). After the introduction, heavy metals may accumulate in aquatic life, enter the food chain and cause serious harm to human health where contamination and exposure are significant (Maigari, *et al.*, 2016). Accumulation of heavy metals in humans can result in a number of health conditions - skin diseases, abdominal cramps, acute abdominal pain, diarrhoea, cold, fever, cough and headache (NORD, 2006). Consequently, most heavy metals (Zinc, Mercury, Iron, Copper, Manganese, Chromium, Lead, Nickel, Cadmium and Arsine) have been listed as metals that can cause diseases by the United States Environmental Protection Authority (USEPA) based on their potential for human exposure and health risks (Birungi *et al.*, 2007). The degree of environmental contamination depends on type of heavy metal, aquatic species, trophic level and feeding pattern (Asuquo *et al.*, 2004).

Aba River has been extensively studied by researchers over the years (Ezeama and Nwamkpa, 2002; Amadi, 2012; Mgbemena, 2014; Amah –Jerry *et al.*, 2017; Nwankwoala and Ekpewerechi, 2017; Egbuonu, 2018). However, there is limited knowledge on the effect of heavy metal contamination of Aba River on the inhabitants of the area. Hence, this study is aimed at evaluating the heavy metal concentration in body fluid of the inhabitants living along Aba River.

Study Area

Aba River, a tributary of Imo River is the major river flowing through Aba town (Figure1). It is located between latitudes 5° 05'N to 5°30'N and Longitudes 7°15'E to 7° 40'E (Figure1) and is characterized by relatively low elevation and near flat topography (Uma, 1989) which enhances its runoff. The River flows in North-South direction and joins the Imo River (Ezigbo, 1989). The river is recharged by precipitation and groundwater (Uma, 1989; Amadi *et al.*, 2010). Aba town is within the sub-equatorial climate zone; characterized by high temperatures and heavy rainfall. The area is characterized by the wet season (May to October) and dry season (November to April); a double maxima rainfall with peaks in July and October with "August break" (short period of dryness) usually occurring in August in between the peaks.

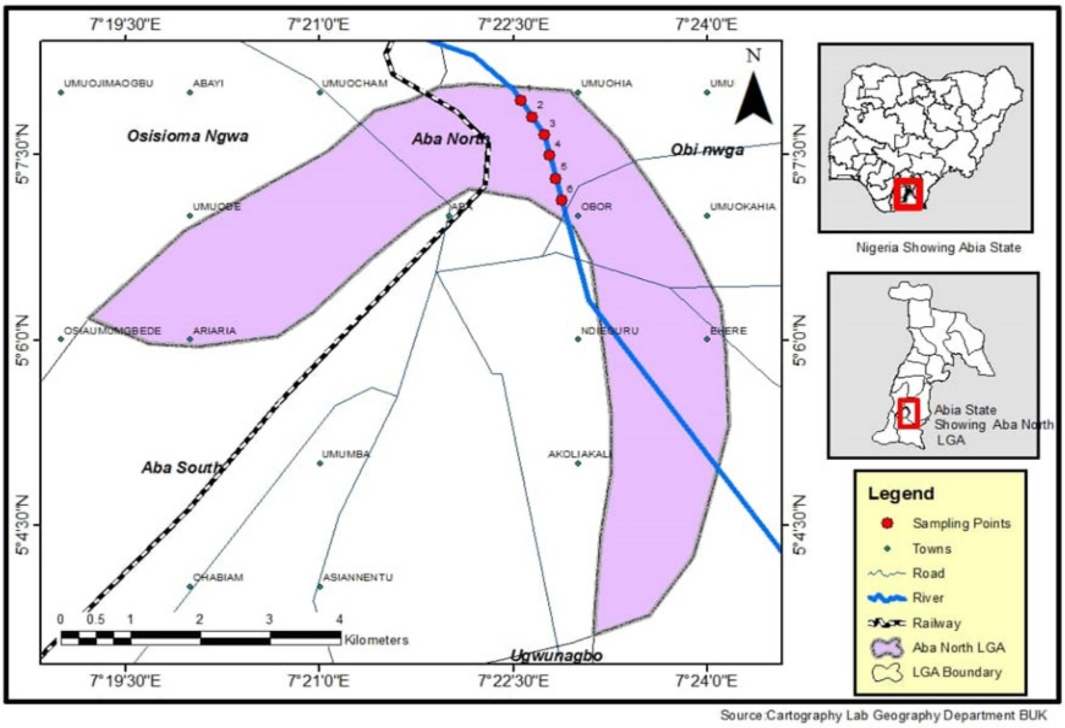

Figure 1: Map of Aba, Abia State, Nigeria showing the sampling stations of Aba River.
Anthropogenic Activities in the study area

Landuse pattern shows that in station 1, landuse is used for both animal and crop farming while key water uses are for irrigation and laundry (Table 1). Stations 2,3,4,5 and 6 have common land uses of commercial and residential. Stations 1 and 2 have land uses covering industrial land use (Table 1). Stations 5 and 6 have a key water usage for domestic uses while station 3 has a key water usage for abattoir (Table 1).

Table 1: Summary of Human Activities carried out at the Sampling Sites

S/ NO	Sampling Site	Land use	Key Uses of Water	River water colour	Type of crops Cultivated	Other activities
1	OkpourUmuobu	Piggery, industries and farming	Irrigation and for Piggery	Light brown	cassava, maize and vegetables	Fishing, Car workshops, dredging and Battery charging, piggery.
2	Emmanuel Ave.	Residential	Laundry	Light brown	Plantain, Bananas and Cassava	Laundry, Swimming, and Car workshops
3	Umuoba Road	Residential	Laundry and Swimming	Greenish	Maize and Vegetables	Laundry, Swimming, dredging activity, abattoir, fetching water for domestic uses and Car workshops
4	AhiaUdele	Industrial, residential and commercial (Abattoir)	Abattoir activities	Greenish and reddish in some area		Swimming,dredging activity, car wash, laundry, open defecation, and electroplating and battery charging.
5	Peoples Road 1	commercial, residential and industrial	Domestic uses	Greenish and reddish in some area	-	Refuse dump, swimming, dredging activity, fetching water for domestic uses, electroplating and battery charging.
6	Peoples Road 2	Commercial and residential	Domestic uses	Greenish	Cassava and maize	Laundry, dredging activity, defecation, swimming, electroplating, car workshops and car washing.

Source: Field work 2020

METHODOLOGY

Water sample collection, analysis and quality control

Six water samples were collected using 1-L plastic bottles, at a depth of 1 meter below the surface of the river. The samples were collected on the 24th of August 2019 and 24th January 2020 between 7am and 12 noon. The samples were collected from Okpolour Umuobu, Emmanuel Ave., Umuoba Road, Ahia Udele, Peoples Roads 1 and Peoples Roads 2 along the river course. The sampling points were selected based on accessibility and nearness to the selected communities along the river. The samples were fixed immediately acidified with Nitric acid (HNO_3) to pH 2 and taken to the laboratory for analysis. The water samples were digested using concentrated Analar nitric acid according to Zhang (2007) and analysed for nickel, zinc, copper, iron, lead, mercury, cadmium, manganese and arsenic. UNICAM 969

Atomic Absorption Spectrophotometer (AAS) that uses air acetylene flame with the appropriate wavelengths of the various elements was used for the heavy metal analysis. Standard curves were obtained by running a prepared standard solution of the various metals. The absorbance values of the metals present in the water samples were determined and by comparing with the standard absorbance of the various heavy metals, the concentrations were determined. This was done in triplicate for each sample and the mean concentration was taken as the actual level of concentration of the heavy metal in mg/L. Background corrections were activated in the analysis of Hg. Quality of the analysis was ensured through replicate analysis, analysis of blank, pre-digestion spikes and analysis of certified reference materials.

Blood sample collection and testing

Six communities that were within Aba River catchment area were selected for the medical outreach.They include Okpolour Umuobu, Emmanuel Ave, Umuoba Road, AhiaUdele, People Road 1 and Peoples Road 2. Aba- Owerri road settlement was used as a control because it is outside the Aba river watershed. The sampling methods were purposive and convenient. Purposive sampling method was used because it is based on communities where the sampling site fell on (Robinson, 2014) while the convenient sampling method was also used because it is only the people that were willing to submit themselves for blood tests that were used (Dörnyei, 2007).

Free medical outreaches were conducted in each of the 6 communities and one community outside as a control. The sampling was conducted on the river bank for each settlement on 7th and 14th March 2020 (Saturdays) when more people visit the river for different purposes. A total of 90 persons from the 6 communities participated and they were interviewed to get their medical history. A semi-structured questionnaire was used and the eligibility of respondents was determined by age (18 years and above).

Seventy-seven (77) persons voluntarily submitted themselves for blood sampling. Sensitization and publicity for the outreach were made in the communities through their various town criers and in churches. The free medical outreach was organized by the researcher and his team in collaboration with some churches. The medical team was made up of three doctors and a medical laboratory scientist. The participants were administered with some basic drugs donated by the churches.

The blood samples were collected as described by Ali and Abduallahi (2017). Blood samples were collected between 7am and 12 noon; when the participants must have taken their breakfasts and have not engaged in any stressful activities. A written informed consent was obtained from each of the participants before a venous blood sample was collected.

Blood samples were collected through venipuncture, 5ml of blood sample was collected by the medical laboratory scientist using pyrogen free sterile disposable syringes. The collection spot on the participant was first cleaned with alcohol (70%) swab. The blood samples were put in well-labelled 5ml capacity EDTA plastic bottles containing K, EDTA as anticoagulant and mixed carefully by shaking. All blood samples collected were immediately stored in a medical cooler box with ice blocks at 4°C in the field, to prevent deterioration before the analysis and taken to the laboratory for analysis. The blood concentrations of nickel, zinc, lead, copper, manganese, cadmium, arsenic, iron and mercury were determined by LC – tandem mass spectrometry.

Data Analysis

The results were summarized using the statistical measures of central tendency and presented as means±SE. Two-way ANOVA without replicate was used to ascertain if there were significant differences of the heavy metals in water and blood in communities and seasons while correlation coefficient was used to determine the relationship between the heavy metal in water and blood. The statistical significance value was set at $p < 0.05$.

RESULTS

Heavy metal content in water

Relatively higher values of the heavy metal concentrations were recorded in the downstream stations (4 – 6) and dry season (Table 2). Zinc (Zn) values ranged between 0.06 and 6.25 mg/l. The lowest and highest values were recorded in stations 1 and 6 in the dry season. The seasonal mean values were 2.56±0.59 mg/l (wet season) and 2.41±0.87 mg/l (dry season). There were significant differences among the stations ($F = 11.61$, $p < 0.05$) while there was no significant difference within the seasons ($F = 0.13$, $p > 0.05$). All the values exceeded 3 mg/l set by SON (2015) except in stations 2 and 6 (wet season) and station 6 in the (dry season).

Manganese (Mn) values ranged between 0.02 and 1.15 mg/l. The lowest values were recorded in stations 2 and 3 while the highest was recorded in station 6 all in the dry season. The seasonal mean values were 0.11±0.01 mg/l (wet season) and 0.25±0.18 mg/l (dry season). There was no significant difference in the stations ($F = 1.15$, $p > 0.05$) and seasons ($F = 0.63$, $p > 0.05$). All the values were lower than 0.2 mg/l set by SON (2015) except in station 6 in the dry season (Table 2).

Mercury (Hg) values ranged between 0.001 and 1.03 mg/l. The lowest and highest values were recorded in stations 3 and 6 in the dry season. The seasonal mean values were 0.02±0.00 mg/l (wet season) and 0.20±0.17 mg/l (dry season). There was no significant difference in the stations ($F = 1.06$, $p > 0.05$) and seasons ($F = 1.20$, $p > 0.05$). All the values were higher than 0.006 mg/l set by WHO (2017) except for stations 1 – 3 in the dry season (Table 2).

Cadmium (Cd) values ranged between 0.003 and 1.12 mg/l. The lowest and highest values were also recorded in stations 3 and 6 in the dry season. The seasonal mean values were 0.06±0.01 mg/l (wet season) and 0.22±0.18 mg/l (dry season). There was no significant difference in the stations ($F = 1.23$, $p > 0.05$) and seasons ($F = 0.84$, $p > 0.05$). All the values were higher than 0.003 mg/l set by SON (2015) except for station 3 in the dry season (Table 2).

Nickel (Ni) values ranged between 0.001 and 0.08 mg/l. The lowest values were recorded in stations 2 and 3 while highest was recorded in station 5 all in the dry season. The seasonal mean values were 0.02±0.00 mg/l (wet season) and 0.03±0.01 mg/l (dry season). There was no significant difference in the stations ($F = 1.55$, $p > 0.05$) and seasons ($F = 0.56$, $p > 0.05$). Stations 2, 5 and 6 (wet season) and stations 5 and 6 (dry season) had values higher than 0.02 mg/l set by SON (2015).

Lead (Pb) values ranged between 0.03 and

1.65 mg/l. The lowest value was recorded in station 1 while highest was recorded in station 6 (dry season). The seasonal mean values were 0.45±0.09 mg/l (wet season) and 0.79±0.25 mg/l (dry season). There was no significant difference in the stations ($F = 2.14$, $p > 0.05$) and seasons ($F = 2.52$, $p > 0.05$). Stations 1, 4 and 5 (wet season) and stations 4 - 6 (dry season) had values higher than 0.02 mg/l set by SON (2015).

Arsenic (As) values ranged between 0.001 and 1.12 mg/l. The lowest value was recorded in station 1 while highest was recorded in station 6 (dry season). The seasonal mean values were 0.07±0.01 mg/l (wet season) and 0.34±0.20 mg/l (dry season). There was no significant difference in the stations ($F = 2.05$, $p > 0.05$) and seasons ($F = 1.15$, $p > 0.05$). All the values exceeded 0.01 mg/l set by SON (2015); relatively higher values were recorded in stations 2, 5 and 6 (wet season) and 3, 5 and 6 (dry season).

Copper (Cu) values ranged between 0.02 and 0.57 mg/l. The lowest value was recorded in station 3 while highest was recorded in station 6 (dry season). The seasonal mean values were 0.24±0.05 mg/l (wet season) and 0.25±0.09 mg/l (dry season). There was no significant difference in the stations ($F = 1.15$, $p > 0.05$) and seasons ($F = 0.00$, $p > 0.05$). All the values lower than 1 mg/l set by SON (2015); though stations 1 – 3 were relatively higher during the wet season while stations 4 – 6 were relatively higher during the dry season (Table 2).

Iron (Fe) values ranged between 0.38and 2.78mg/l. The lowest value was recorded in station 4 (wet season) while highest was recorded in station 6 (dry season). The seasonal mean values were 0.72±0.12 (wet season) and 1.13±±0.45 mg/l (dry season). There was no significant difference in the stations ($F = 2.47$, $p > 0.05$) and seasons ($F = 1.17$, $p > 0.05$). Stations 1 and 3 were within 0.3 mg/l set by SON (2015). Other exceeded the limit with stations 5 and 6 having relatively higher values in both seasons (Table 2).

Table 2: Spatial and seasonal values of the heavy metals concentrations in waters of Aba River

Heavy Metal	Season	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	mean±SE	Station F-value	Season F-value	SON (2015)
Zinc	Wet	1.262	3.160	2.110	1.462	2.208	5.160	2.56±0.59	11.61	0.13	3
(mg/L)	Dry	0.062	2.180	1.103	1.862	2.989	6.250	2.40±0.87	P<0.05	P >0.05	
Manganese	Wet	0.081	0.106	0.120	0.100	0.122	0.143	0.11±0.01	1.15	0.63	0.2
(mg/L)	Dry	0.031	0.016	0.020	0.132	0.157	1.148	0.25±0.18	P >0.05	P >0.05	
Mercury	Wet	0.016	0.024	0.014	0.032	0.014	0.033	0.02±0.00	1.06	1.2	0.001
(mg/L)	Dry	0.006	0.004	0.001	0.082	0.091	1.033	0.20±0.17	P >0.05	P >0.05	
Cadmium	Wet	0.046	0.088	0.046	0.058	0.052	0.114	0.06±0.01	1.23	0.84	0.003
(mg/L)	Dry	0.020	0.021	0.003	0.089	0.091	1.124	0.22±0.18	P >0.05	P >0.05	
Nickel	Wet	0.026	0.012	0.011	0.024	0.022	0.018	0.02±0.00	1.55	0.56	0.02
(mg/L)	Dry	0.018	0.001	0.001	0.034	0.084	0.026	0.03±0.01	P >0.05	P >0.05	
Lead	Wet	0.163	0.655	0.481	0.226	0.448	0.704	0.45±0.09	2.14	2.52	0.01
(mg/L)	Dry	0.026	0.255	1.041	0.526	1.221	1.654	0.79±0.25	P >0.05	P >0.05	
Arsenic	Wet	0.021	0.060	0.066	0.053	0.083	0.112	0.07±0.01	2.05	1.15	0.01
(mg/L)	Dry	0.001	0.025	0.012	0.781	0.101	1.121	0.34±0.20	P >0.05	P >0.05	
Copper	Wet	0.412	0.310	0.106	0.226	0.114	0.281	0.24±0.05	1.15	0.00	1
(mg/L)	Dry	0.112	0.110	0.016	0.449	0.229	0.572	0.25±0.09	P >0.05	P >0.05	
Iron	Wet	0.661	0.760	0.553	0.380	0.982	1.180	0.72±0.12	2.47	1.17	0.3
(mg/L)	Dry	0.221	0.660	0.153	0.790	2.182	2.780	1.13±±0.45	P >0.05	P >0.05	

Source: Field work 2020

Assessment of Metallic Element in blood

Heavy metals were detected in the bloods of the participants from the communities and control of Aba - Owerri Road participants (Table 3). Four (4) metals - Zn, Mn, Fe and Pb - out of nine (9) evaluated were detected in the blood samples from the upstream stations - station 1 (Okpolour Umuobu), station 2 (Emmanuel Ave), station 3 (Umuoba Road) and control (Aba-Owerri Road). However, between five (5) and eight (8) metals were recorded in the blood samples collected from the downstream stations - station 4 (Ahia Udele), station 5 (Peoples Road 1) and station 6 (Peoples Road 2). Generally, the prevalence of metalsin the blood was more among the female (51.6%) than the male (48.4%) though not significantly different (Table 3).

Table 3: Summary of people with heavy metals in their blood in the stations and control.

Stations	Communities	Heavy Metals	Gender Male (%)	Gender Female (%)	Total %
1	Okpolour Umuobu	Zn	64	27	91
		Mn	45	18	63
		Fe	64	36	100
		Pb	27	18	45
2	Emmanuel Ave	Zn	27	55	82
		Mn	9	55	64
		Fe	27	64	91
		Pb	27	64	91
3	Umuoba Road	Zn	73	27	100
		Mn	27	27	54
		Fe	64	27	91
		Pb	45	45	90
4	Ahia Udele	Zn	64	34	100
		Mn	45	36	81
		Fe	64	27	91
		Pb	55	36	91
		Ni	18	9	27
5	Peoples Road 1	Zn	27	45	72
		Mn	45	55	100
		Fe	36	64	100
		Pb	64	27	91
		Hg	18	27	45
		Cd	9	9	18
		Ni	18	9	27
		Cu	9	9	18
6	Peoples Road 2	Zn	27	64	91
		Mn	18	45	63
		Fe	27	54	91
		Pb	27	64	91
		Hg	9	27	36
		Cd	9	9	18
		Ni	9	9	18
		Cu	9	9	18

Control	Aba Owerri Road	Zn	54	27	81
		Mn	27	36	63
		Fe	27	64	91
		Pb	36	45	81

Source: Field work 2020

The mean concentration of Zn in the blood ranged between 4.70±2.54 and 1.25±1.67 µg/L (Table 4). The lowest value was recorded in station 1 while the highest was in station 5.Stations 4 – 6 were significantly higher ($p<0.05$) than the other stations and control.

Table 4: Concentrations of metallic elements (heavy metals) in the blood of people in communities having contacts with Aba River

Communities	Zn (µg/L)	Mn (µg/L)	Hg (µg/L)	Cd (µg/L)	Fe (µg/L)	Ni (µg/L)	Pb (µg/L)	Cu (µg/L)
Okpolour Umuobu	4.70[c]± 2.54	0.023[c] ±02	ND	ND	0.12[c]± 0.01	ND	2.80[a]± 0.84	ND
Emmanuel Avenue	5.33[bc]± 2.29	0.037[c] ±0.02	ND	ND	0.48[b]± 0.38	ND	0.47[b]± 0.30	ND
Umuoba Road	7.18[b]± 1.78	0.350[b] ±0.16	ND	ND	0.83[a]± 0.19	ND	0.97[b]± 0.21	ND
AhiaUdele	9.27[a]± 2.05	0.667[a] ±0.19	ND	ND	0.95[a]± 0.40	0.0080[a] ±0.00	0.89[b]± 0.13	ND
Peoples Road 1	11.25[a] ±1.67	0.791[a] ±0.13	0.003[a] ±0.00	0.0050[a] ±0.00	0.87[a]± 0.10	0.0070[a] ±0.00	1.05[b]± 0.25	0.070[a] ±0.03
Peoples Road 2	10.33[a] ±2.78	0.783[a] ±0.08	0.003[a] ±0.00	0.0045[a] ±0.00	0.85[a]± 0.11	ND	1.02[b]± 0.21	0.055[a] ±0.01
Aba-Owerri Road	6.33[bc]± 1.12	0.066[c] ±0.03	ND	ND	0.60[b]± 0.18	ND	2.33[a]± 1.22	ND

ND - Not Detected

Values are mean± standard deviation of replicated determinations (n=11). Means in the same column followed by different superscripts are significantly different ($p<0.05$).

Source: Field work, 2020

Manganese mean concentration ranged between 0.023±0.20 7.91±0.13 μg/L (Table 4). The lowest and highest values were also recorded in stations 1 and 5 respectively. Stations 3 – 6 were significantly higher ($p<0.05$) than stations 1, 2 and control. Fe ranged between 0.12±0.01 and 0.95±0.40 μg/L. The lowest value was recorded in station 1 while the highest was recorded in station 3. Stations 3 – 6 were significantly higher ($p<0.05$) than the others. Pb ranged between 0.47±0.30 and 2.80±0.84 μg/L. The lowest value was recorded in station 2 while the highest was recorded in station 1. Station 1 and control were significantly higher ($p<0.05$) than the others. Hg, Cd and Cu were only recorded in stations 4 and 5. Hg recorded the same value (0.003 μg/L) in both stations while Cd was 0.0045±0.00 μg/L (station 5) and 0.0050a±0.00 μg/L (station 4) and Cu – 0.055±0.01 μg/L (station 5) and 0.070±0.03 (station 4). On the other hand, Ni was recorded only in stations 4 (0.0070±0.00 μg/L) and 3 (0.0080a±0.00 μg/L). Generally, lower values were recorded in station 1 while higher values were recorded in station 5 with a few exceptions.

The values observed were however lower than the blood metal cutoff levels reported by Cusick et al. (2018) Table 5.

Table 5: Cutoffs for blood metal levels

Heavy Metal	Cutoff Point	Source
Arsenic	3.12 μg/L	Goullé*et al.,* 2015
Cadmium	0.15 μg/L	CDC, 2017
Copper	1495 μg/L 20 μg/L	Goullé*et al.,* 2015
Lead	50 μg/L 100 μg/L	CDC, 2017
Manganese	18.3 μg/L	CDC, 2017
Nickel	2.62 μg/L	Goullé*et al.,* 2015
Zinc	5234 μg/L	Goullé*et al.,* 2015

Correlation coefficient (r0.01(2)14 = 0.623) showed some significant positive correlations within the different media (water and blood respectively) and in between the media (Table 6). However, two significant negative correlations were recorded in between the media. In water, Zn correlated with Mn (0.747), Hg (0.704), Cd (0.742), Pb (0.715) and Fe (0.809);Mn correlated Hg (0.994), Cd (0.997), Pb (0.716), As (0.833), Cu (0.671) and Fe (0.802); Hg correlated with Cd (0.997), Pb (0.713), As (0.841), Cu (0.659) and Fe (0.782); Cd correlated with Pb (0.704), As (0.829), Cu (0.670) and Fe (0.781); Pb correlated only with Fe(0.789) and As correlated with Cu (0.772) and Fe (0.648). In the blood, Zn correlated with Mn (0.989), Hg (0.799), Cd (0.805), Ni (0.626), Cu (0.806) and Fe (0.837) (Table 6).

Table 6: Correlation between heavy metals in water and in the blood of people in communities having contacts with Aba River

	Zn-Water	Mn-Water	Hg-Water	Cd-Water	Ni-Water	Pb-Water	As-Water	Cu-Water	Fe-Water	Zn-Blood	Mn-Blood	Hg-Blood	Cd-Blood	Ni-Blood	Pb-Blood	Cu-Blood	Fe-Blood
Zn-Water	1																
Mn-Water	**0.747**	1															
Hg-Water	**0.704**	**0.994**	1														
Cd-Water	**0.742**	**0.997**	**0.997**	1													
Ni-Water	0.154	0.140	0.127	0.097	1												
Pb-Water	**0.715**	**0.716**	**0.713**	**0.704**	0.349	1											
As-Water	0.581	**0.833**	**0.841**	**0.829**	0.177	0.586	1										
Cu-Water	0.571	**0.671**	**0.659**	**0.670**	0.309	0.363	**0.772**	1									
Fe-Water	**0.809**	**0.802**	**0.782**	**0.781**	0.592	**0.789**	**0.648**	0.605	1								
Zn-Blood	0.339	**0.702**	0.281	0.214	0.188	0.229	**0.757**	-0.612	0.438	1							
Mn-Blood	0.335	**0.686**	0.359	0.222	0.221	0.179	**0.736**	-0.573	0.377	**0.989**	1						
Hg-Blood	0.605	**0.746**	0.117	0.438	0.144	0.459	**0.806**	-0.288	**0.875**	**0.799**	**0.749**	1					
Cd-Blood	0.562	**0.724**	0.073	0.392	0.157	0.434	**0.785**	-0.316	**0.859**	**0.805**	**0.748**	**0.998**	1				
Ni-Blood	-0.403	-0.063	0.125	-0.338	0.521	-0.411	0.030	-0.442	-0.244	**0.626**	0.612	0.199	0.236	1			
Pb-Blood	-0.426	-0.583	-0.366	-0.422	**0.641**	**-0.666**	-0.602	0.563	-0.086	-0.406	-0.371	-0.157	-0.156	-0.224	1		
Cu-Blood	0.505	**0.693**	0.017	0.330	0.172	0.400	**0.753**	-0.349	**0.834**	**0.806**	**0.742**	**0.989**	**0.997**	0.280	-0.154	1	
Fe-Blood	0.268	**0.694**	0.340	0.160	-0.196	0.304	**0.695**	**-0.796**	0.076	**0.837**	**0.851**	0.427	0.427	0.552	-0.712	0.425	1

Boldface Correlationsare significant at the 0.01 level (2-tailed), DF = 14 = 0.623

Mn correlated with Hg (0.749), Cd (0.748), Cu (0.742) and Fe (0851); Hg with Cd (0.998) and Cu (0.989) while Cu correlated only with Cu (0.997). Across the media, Mn (water) correlated with Zn (0.702), Mn (0.686), Hg (0.746), Cd (0.693) and Fe (0.694) in blood. Ni (water) correlated only with Pb (0.641) in Blood. As (water) correlated with Zn (0.757), Mn (0.736), Hg (0.806), Cd (0.785), Cu (0.753) and Fe (0.695) in blood and iron (water) correlated with Hg (0.875), Cd (0.859) and Cu (0.834) in blood.The two negative correlations were Pb (water) correlated significantly with Pb(-0.666)in blood and Cu (water) correlated significantly with Fe (-0.796) in blood (Table 6).

DISCUSSION

The four (4) metals recorded in the blood samples from the upstream stations and control is a reflection of minimal anthropogenic activities in the areas while the downstream stations located in the hub of the city recorded between five (5) and eight (8) metals in the blood samples. This could be attributed to nature and intensity of human activities in the area compared with the upstream stations and control. Minimal pollution of any environmental media can occur through geogenic contamination (Davraz, 2015; Deniz and Çalık, 2016) but most cases of high level pollution are from anthropogenic sources - domestic, industrial, and agricultural sources (Huang et al., 2020; Desiree et al., 2021; Anyanwu et al., 2022 a, b). Some of the activities observed in and around the river during the study are potential sources of heavy metals (abattoir waste disposal, refuse disposal, dredging, electroplating, car workshops and car washing, etc.). Amah-Jerry et al., 2017. The presence of heavy metals in the blood of participants from the control station could be attributed to sources other than contact with the river (ingestion and dermal contact). Inhalation could be a possibility and has been reported as one of the major sources of human heavy metal contamination (Faisal et al., 2021) because the area usually experience heavy vehicular traffic and build up for greater part of each day.

The heavy metals in water totally or partially exceeded limits set by SON (2015) except manganese and copper. All recorded relatively higher values in the downstream stations which could be attributed to the intensity of anthropogenic activities in the stations. This has also collaborated the high number of people with metals in their blood from those stations compared with the upstream stations. Lowest and highest values generally occurred in some upstream stations and downstream stations respectively during the dry season. This is season influencing the concentrations of water quality parameters (Ling et al., 2017). Low values can be recorded in dry season due no allochthonous input or high values due concentration occasioned by little or no precipitation, low flow velocity, high temperatures and high evaporation (Haque *et al.*, 2019;Anyanwu *et al.* 2022a, b).

The heavy metal mean concentrations in the blood followed same trend observed in water. Generally, lower values were recorded in the upstream stations while higher values were recorded in downstream stations (especially in station 5) with a few exceptions which are not unconnected with the prevailing anthropogenic activities. For instance, Hg, Cd and Cu were only recorded in stations 4 and 5. On the other hand, significantly high lead values recorded in station 1 and control could be due to its availability and ease of entering into environmental compartments; which has made lead poisoning common in Nigeria (Orisakwe et al., 2014). However, the heavy metal values recorded were lower than the blood metal cutoff levels reported in Cusick et al. (2018).

A high negative or positive correlation coefficient value between two indexes is an indication of stronger correlations between them (Mukaka, 2012). Correlation coefficient showed some significant positive correlations within the different media (water and blood respectively) and in between the media. This is an indication that changes in the concentrations of the heavy metals within one medium or between the media affect each other in the same direction (Majhi and Biswal, 2016). In order words, as one metal is increasing within or between media, a correlated metal is also increasing; indicating common source or influence. On the other hand, the two negative correlations recorded between Pb (water) and Pb (blood) and Cu (water) and Fe (blood) indicated that change in Pb and Cu in water was predicated by change in Pb and Fe in blood in the opposite direction (Majhi and Biswal, 2016). In order words, as Pb and Cu are increasing in water, Pb and Fe are decreasing in blood. It is a clear indication that the concentration of Pb in the water did not influence the concentration in the blood but the relationship between Cu and Fe can be attributed to inhibition. Studies have shown the copper plays a major role in iron metabolism; high concentration of copper can inhibit iron uptake (Chanand Rennert, 1980; Arredondo et al., 2006).

CONCLUSIONS

The study has established that Aba River was polluted with heavy metals among others; which reflected in level of heavy metals in the body fluid (blood) of people who live around and use it for their daily domestic and other activities. The water of the river is contaminated due to high concentrations of Zn, Mn, Fe and Pb which were largely from anthropogenic sources. High concentrations were high in dry season and downstream stations where the anthropogenic activities were intense. The high levels of Zn, Mn, Fe and Pb recorded in the bloods of the participants from this study communities portends potential public health risk. A drastic action must be taken to stem the trend.

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