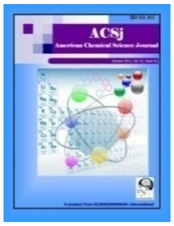

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Water Quality Characteristics of Floodwater from ABA Metropolis, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors ECO, IOC and DE designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors ECO, DE and IOC managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To report the extent of contamination of floodwater by physicochemical parameters (total suspended solids, total dissolved solid, chemical oxygen demand, biochemical oxygen demand, dissolved oxygen, electrical conductivity, nitrate, nitrite, chloride and sulphate and heavy metals (Zn, Cu, Pb, Hg, As and Cd).
Study Design: Triplicate floodwater samples collected from ten different sample points in Aba metropolis, Abia State, in the month of July, 2012 were analyzed for physicochemical parameters and heavy metal concentrations.
Place and Duration of Study: The study was carried out at Temple-Gate polytechnic Aba and the analysis was conducted at the Industrial and Analytical Chemistry Laboratory of University of Port Harcourt, River's State, Nigeria at mid July, 2012.

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Methodology: Nitrate, nitrite and sulphate were quantitatively determined by spectrophotometric method while chloride was determined by titrimetric method. Heavy metals in water were determined by atomic absorption spectrophotometry while BODs, COD, DO, TDS, TSS, pH, turbidity and Hardness of water were determined by standard methods.
Results: Results indicated a wide variation in the concentrations of different physicochemical parameters and those of heavy metals at various study sites. Correlation coefficient analysis of data showed statistically significant positive correlation between the following two pairs of parameters: Electrical conductivity and total dissolved solid; Sulphate and hydrogen ion concentration; And nitrates and sulphate. Others are cadmium and chemical oxygen demand; Mercury and cadmium as well as arsenic and hydrogen ion concentration. However, significant negative associations were observed between arsenic and copper; Cadmium and total dissolved solid; And lastly nitrate and chemical oxygen demand. Furthermore, highly significant positive relationship was observed between lead and dissolved oxygen while highly significant negative association occurred between sulphate and chemical oxygen demand. Among the metals determined, Cu had the highest concentration while Hg had the lowest concentration.
Conclusion: The values obtained for the anions and heavy metals were higher than the tolerance limits for aesthetic and inland surface water quality, indicating pollution of the sample areas.

Keywords: Floodwater; physicochemical parameters; heavy metals; Aba metropolis; Nigeria.

1. INTRODUCTION

The term flood refers to an overflow of a large amount of water beyond its normal limits over a normally dry land. Flood affects and damage public utilities, properties, agriculture, economy and could lead to loss of human lives [1]. Flooding in most urban areas in Nigeria is a combined effect of excessive precipitation and insufficient flow channel capacity of sewer system [1]. Flood has an excellent ability to disperse waste generated by domestic, agricultural and industrial activities and has lead to increased incidence of gastrointestinal diseases at epidemic level. The study area is very highly populated with people and consisting of mainly a relatively flat terrain. During raining season the ground is usually saturated and water continues to accumulate due to its inability to runoff quickly enough. None existing or poorly implemented blue-print for urban development, very poor drainage system and poor road networks in Aba have immensely compounded the flooding problem. In the low-lying areas some of the flood water moves away from the flood plain into a local river which serves as a source of domestic water for communities that lives within such vicinity. With the increasing urbanization, commercial, agriculture and industrial activities, household wastes and effluents containing heavy metals, compounds of chlorides, nitrites, nitrates, sulphates deposited on the soil could have been conveyed into residential areas, rivers and agricultural lands by floods [2,3].

This paper was designed to investigate the concentrations of Heavy metals (lead, cadmium, mercury, zinc, copper, and arsenic) as well as some physicochemical parameters: Anions, total suspended solids, total dissolved solid, oxygen demands, dissolved oxygen (DO), electrical conductivity (EC), turbidity and hardness of flood waters in Aba metropolis.

2. MATERIALS AND METHODS

2.1 Study Area and Data Collection

Aba metropolis is the commercial nerve city of Abia State located in south eastern Nigeria which lies within coordinates 5°07' N and 7°22' E (Fig. 1).

One sample for each station in triplicate was collected in plastic bottles in the month of July, 2012, which is the middle of rain season in south- eastern Nigeria. The samples were properly labeled prior to analysis as 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 based on their locations: Aba-Enugu Express, Okigwe road, Brass junction, MCC Junction, Ukaegbu Street, Umugasi, Umuojima, Borrow Pit, Ogbohill-waterside, and Ariaria respectively. The floodwater samples were filtered with whatman No 42 filter paper and transferred into prewashed two litres plastic containers with screw caps followed by the addition of 5 ml of concentrated nitric acid for preservation.

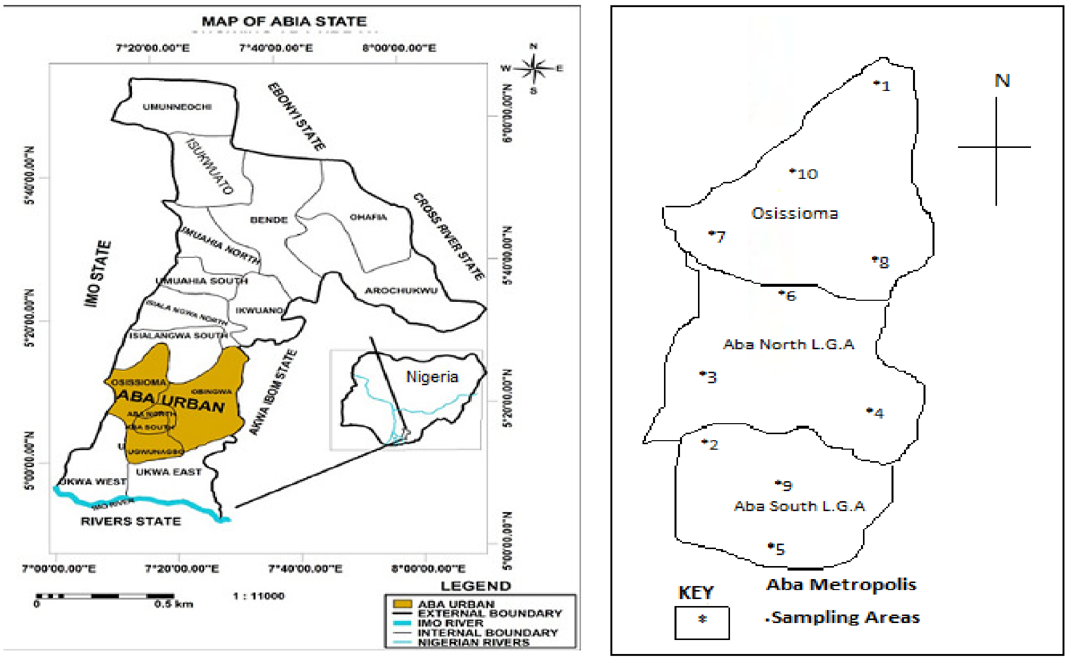

Fig. 1. Abia state map (Nigeria) showing Aba Metropolis and sampling areas (Adapted from Nwoko Alex, 2013)

2.2 Sample Analysis

2.2.1 Determination of physicochemical parameters

The pH of the samples was measured by using the Electro-metric methods (pH meter Jenway 3015). Electric conductivity in µs/cm was determined using a salinity-conductivity meter (model, YSI EC 300). Total dissolved solids were carried out by gravimetric method according to American Public Health Association [4], dissolved oxygen was determined via Winkler's method by azide modification of iodometric method [5,6]. Nitrate, Nitrite and sulphate were determined by uv-spectrophotometric methods [7]. Turbidity (NTU) in water was measured by Nephelometric method [6,8,9] and while hardness was measured by the EDTA titration method [10]. Concentration of chloride was determined argentometrically by titration of 50ml of sample against silver nitrate indicator. Total suspended solids, biochemical oxygen demand, chemical oxygen demand of the water samples were determined by standard methods [4,11].

2.2.2 Heavy metal determination

Heavy metal estimation was done by using Atomic absorption spectrophotometer as per the methods of [4,12].

2.2.3 Statistical analysis

Results are presented as mean and three replicate measurements were performed (n = 3). Pearson's correlation analysis was carried out using IBM SPSS statistics 20 software in order to substantiate the association among floodwater parameters determined in this study.

3. RESULTS AND DISCUSSION

The variation in physicochemical parameters of the studied samples were shown in Figs. 2 and 3.

3.1 Hydrogen Ion Concentration (pH)

The pH values of floodwater in the studied station (Fig. 2a.) ranged from 5.20 to 8.60. The maximum value was recorded at station 10 while the minimum pH value was measured at station 6. The pH of the samples was within the tolerance limits 5.5 to 9.0 prescribed by India and Philippine regulations of inland surface water subject to pollution [13,14]. The decrease in pH could be as a result of contamination of floodwater by inorganic compounds, and effluent produced due to commercial and industrial activities. Low pH may also results from deposition of CO_2 during precipitation especially within the rainy season. The amount of dissolved CO_2 which forms carbonic acid in water determines to large extent the pH of surface water. Organic acids are produced from decaying vegetation and the dissolution of sulphite minerals decreases also the pH of floodwater [10].

3.2 Electric Conductivity

Electrical conductivity ranged from 645.30 to 2578.80 µS/cm (Fig. 2a). Noticeably four water samples from stations 1, 2, 3 and 8 were above the permissible limit of 1400 µS/cm [15,16], which could be attributed to the presence of higher amount of dissolved inorganic substances in ionized form. The values were however, within the tolerance limits of 2250 mg/L recommended for industrial waste water discharged into inland water for irrigation purpose [17].

3.3 Total Dissolved Solid (TDS)

Minimum and maximum values of TDS were recorded at stations 1 (400.0 mg/L) and 3 (1750.0 mg/L) respectively (Fig.2a). TDS values in most of the sampling stations were below 1000 mg/L except for stations 3 (1750 mg/L) and 8 (1110.40 mg/L) respectively (Fig. 2a). Water with very low concentration of TDS has a characteristic insipid taste while higher levels of TDS impacts objectionable mineral taste and is capable of causing excessive scaling in boilers, heaters as well as water pipes [3,18]. This water is unsuitable for many industrial as well as agricultural applications and the high levels of TDS may be attributed to indiscriminate discharge of agricultural and domestic wastes [19].

3.4 Turbidity and Hardness

Evidently data obtained for turbidity of water samples in this study ranged from 19.70 to 234.70 NTU (Fig. 2a). These values were higher than the standard water quality guidelines: 1.0 NTU [20,21] and 5.0 NTU [15]. The presence of silt, clay, organic and inorganic colloidal particles in water might have contributed to higher values of turbidity [22]. The absolute minimum value of hardness of water (1011.0 mg/L) was recorded at stations 10 while the absolute maximum value (2875.5 mg/L) was observed at station 5 (Fig. 2a). It is apparently clear that these values were well above the prescribed permissible and desirable limits of 150 mg/L and 300 mg/L respectively [15,13]. Flood water with total hardness between 150 and 300 mg/L is said to be hard [23]. The higher values of hardness could be attributed to discharge of calcium carbide by automobile –welding workshops [24], effluent from paint, chalk and ceramic industries as well as the dissolution of land derived carbonates and bicarbonates into the water [25].

3.5 Total Suspended Solid (TSS) and Dissolved Oxygen (DO)

The results revealed that minimum and maximum values of TSS were observed at stations 10 (240.2 mg/L) and 6 (4575.0 mg/L) respectively (Fig. 2a). High levels of TSS could be due to discharge of organic wastes into water, occluding light and thereby causing serious drop in photosynthesis by phytoplanktons as well as other bottom dwelling plants [26]. Dissolved oxygen level is greatly lowered due to the drop in photosynthesis and also because the decay process of death plants consumes remaining oxygen in water. The values of dissolved oxygen ranged from 1.10 to 3.30 mg/L (Fig 2b), which were below 3.0 mg /L or higher recommended for inland surface water standard except for stations 1 (3.0mg/L) and 2 (3.30 mg/L) [17,18]. Aquatic organisms exposed to dissolved oxygen level less than 2.5 mg/L for few days are less likely to survive while DO value of 5.0 mg/L is suitable for most of fish population [27].

3.6 Biochemical Oxygen Demand (BODs) and Chemical Oxygen Demand (COD)

The biochemical oxygen demand of floodwater ranged from 0.25 to 1.20 mg/L (Fig. 2b). The maximum BODs content (1.20 mg/L) was recorded at station 1 while the lowest value (0.25 mg/L) was reported at station 7. The COD values ranged from 1.00 to 1.86 mg/L with maximum value (1.86 mg/L) and minimum value (1.00 mg/L) obtained from stations 10 and 7 respectively (Fig. 2b). It should also be noted that COD contents recorded at stations 5 and 6 were below detection limit [28]. The very low content of both BODs and COD could be a consequent of over consumption of dissolved oxygen due to microbial decomposition of high contents of dissolved and suspended organic matter or pollutant in water [29]. The BODs values obtained for all the samples were significantly lower than 4 to 5 mg/L prescribed limit for class II type of inland surface water [30]. The COD values were lower than 40 mg/L prescribed by FEPA [19].

3.7 Nitrate (NO_3^-) and Nitrite (NO_2^-)

The concentration of nitrite and nitrate in all the samples studied as shown in Fig. 3, ranged from 71.20 to 640.0 mg/L and 420.70 to 2336.1 mg/L respectively. The World Health Organization has a recommended value (50 mg/L) for nitrate [30].

The US EPA has established guideline values for the maximum level of nitrate-nitrogen and nitrite-nitrogen of 10 mg/L and 1.0 mg/L respectively [28]. The results obtained for nitrate and nitrite concentration in all the samples were higher than the guideline values.

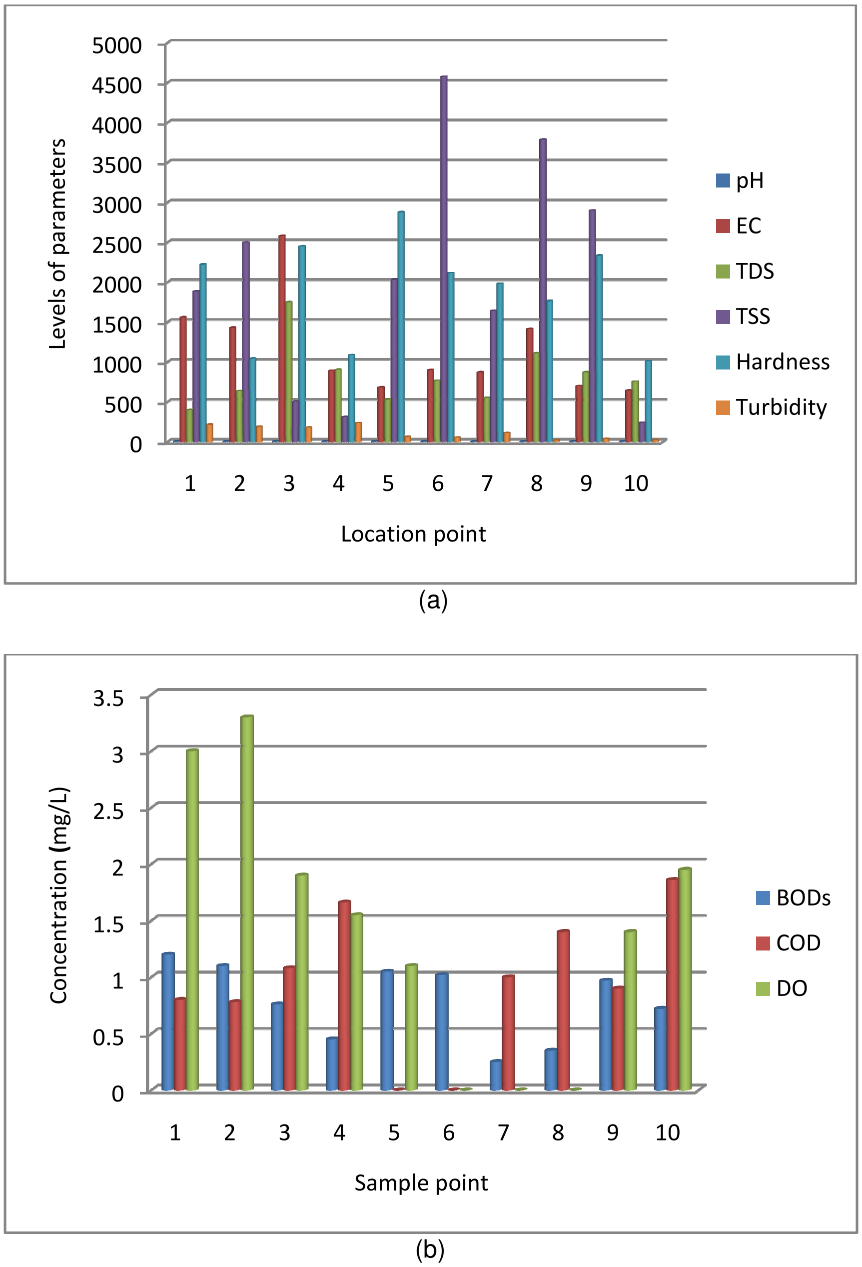

Fig. 2. Variations in levels of physicochemical parameters with sample location

All the physico-chemical parameters were expressed in mg/L except Turbidity (NTU)

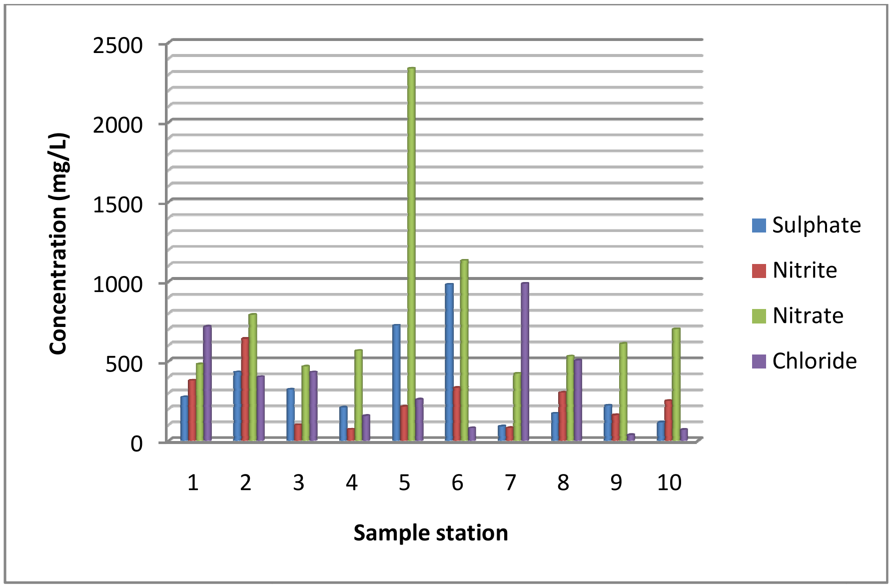

Fig. 3. Variation in anion levels with sample location

The nitrate concentrations of the samples were also significantly higher than the tolerance limits of 10 mg/L prescribed by India law and 5 mg/L recommended by Philippine regulation for inland surface water [13,14]. The source of high nitrate and nitrite in floodwater may be due to runoff water which contain fertilizers and manure from agricultural land. Other sources are industrial effluents, sewage and wastewater [30]. It was observed that the concentration of nitrate in all the samples was significantly higher than the values obtained for nitrite. This may be as a result of nitrification process that takes place in soil and flood water [3]. Ammonium ion is progressively oxidized by microorganisms first to nitrite and then to nitrate. Nitrate, naturally present in green leafy and water supply is immediately converted to nitrite by bacterial residing in the mouths and in the intestine [3,30].

3.8 Chloride (Cl^-) and Sulphate (SO_4^{2-})

Chloride concentration as shown in Fig. 3 ranged from 34.60 to 986.0 mg/L. The values of chloride in most of sampling stations were well above the permissible limit (200 mg/L) recommended by WHO [28]. However, concentration of chloride in uncontaminated water is often below 10 mg/L [31]. High concentration of chloride and contamination of sampling stations may be attributed to the discharge of grease, oil, pesticides and other chloride containing compounds (especially inorganic chlorides) from industrial and municipal activities as well as from water softening and agricultural runoff [31]. Sulphate concentration ranged from 90.0 to 980.6 mg/L (Fig. 3). Sampling station 6 (980.6 mg/L) and station 7 (90.0 mg/L) recorded the maximum and minimum concentrations of sulphate ion respectively. Sulphate levels between 250 and 300 mg/L is good enough to support aquatic life in inland surface water [18]. Sulphate in the form of hydrogen tetraoxosulphate (vi) Acid which constitutes electrolyte for wet cell batteries, discharged by battery chargers and agricultural runoff (super sulphate fertilizers) might have contributed to the overall concentration of SO_4^{2-} ion in floodwater [31].

3.9 Heavy Metals

Heavy metal in floodwater samples was determined by Atomic Absorption Spectrophotometer. The concentration of heavy metals in floodwater is shown in Fig. 4. The concentration of Zn and Cu ranged from 3.20 to 11.63 mg/L and 17.30 to 89.5 mg/L respectively (Fig. 4). The maximum permissible limit recommended by prescribed by Indian regulation for Zn and Cu in inland surface water is 5.0 mg/L and 3.0 mg/L respectively [13]. It was observed that seven stations (1, 2, 3, 6, 7, 9 and 10) had higher zinc concentration compared to the recommended 5.0 mg/L. Similarly the concentration of copper in all the sampling stations was significantly higher than the recommended 3.0 mg/L, indicating contamination of the floodwater samples by these metals [32]. The sources of Zn and Cu are mainly through runoff from refuse dumps and industrial effluents [33]. The concentration of Pb and Cd in this study (Fig. 3) ranged from 0.03 to 9.70 and 0.003 to 1.24 mg/L respectively.

Results obtained for analysis of lead revealed that samples at all the stations except station 9 (0.03 mg/L) recorded concentration values higher than 0.1 mg/L recommended for all classes of surface inland waters according to regulation authorities in Poland, India and Sri-Lanka [34]. Similarly, samples analyzed from all the stations had higher Cd content compared to the maximum permissible limits of 0.005mg/L and 0.005 to 0.1 mg/L prescribed by both US EPA [23] and Polish law [34] respectively, except those recorded at stations 3, 4 and 10. High level of Pb and Cd in the water samples could be from used dry cell batteries and tires and non serviceable metal scraps from dumpsites [34]. The concentration of mercury ranged from 0.003 to 0.50 mg/L (Fig. 4). The maximum and minimum concentration of Hg were found in stations 10 (0.50 mg/L) and 1 (0.003 mg/L) respectively. The concentration of Hg in all the stations except station 3 (below detectable limit) were higher than the approved limits of 0.001 mg/L and 0.001mg/L [35] for surface water. The maximum and minimum concentration of as are 0.15 (station 3) and 0.01 mg/L (stations 1 and 8) respectively (Fig. 4). Polish laws and Indian regulations set the maximum concentration of arsenic in surface water as 0.05 to 0.2 mg/L and 0.2 mg/L respectively [35]. Interestingly, all the samples had values which were within the permissible limit for Arsenic in inland surface water.

Toxicology studies on heavy metals revealed that exposure of Pb at high concentration could lead to gastrointestinal tract and central nervous system disorders, as well as kidney failure and eventual death. Arsenic is associated with circulatory system disorder, cancer and skin damage [36,37]. Copper at high doses is linked to anaemia, liver and kidney damage [37]. Bioaccumulation of mercury in human body can cause lungs, kidneys and permanent brain damage. High level of Cd in the blood stream leads to kidney dysfunction [38].

Pearson's correlation analysis was applied to data in order to evaluate and confirm the association among the physicochemical as well as heavy metal parameters of flood water samples (Table.1). Generally, direct relationship exists when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of another parameter [21].

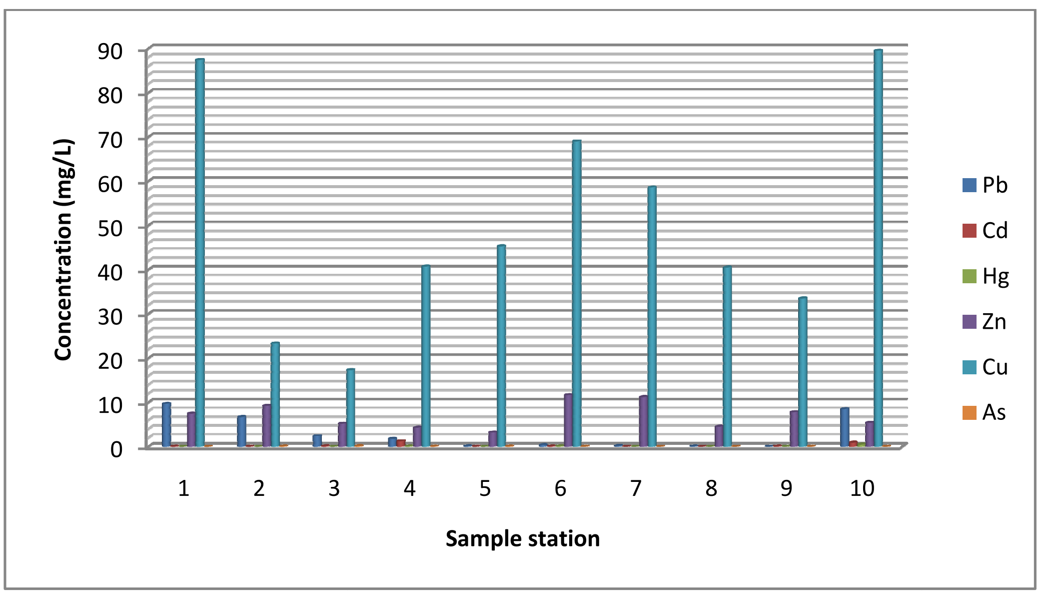

Fig. 4. Variation of heavy metal concentration with sampling station

Table 1. Pearson correlation matrix of physicochemical parameters of floodwater samples

	pH	EC	TDS	TSS	NTU	BODs	COD	DO	SO_4^{2-}	NO_3^-	NO_2^-	Cl^-	Pb	Cd	Zn	Hg	Cu	As
pH	1																	
EC	0.46	1																
TDS	0.46	0.67*	1															
TSS	0.38	-0.15	-0.19	1														
NTU	0.12	0.49	0.03	-0.45	1													
BODs	0.26	0.06	-0.29	0.23	0.12	1												
COD	-0.52	0.07	0.31	-0.59	0.10	-0.60	1											
DO	-0.15	0.33	-0.11	-0.44	0.58	0.59	0.16	1										
SO_4^{2-}	0.72*	-0.09	-0.14	0.54	-0.12	0.57	-0.86**	-0.17	1									
NO_2^-	0.14	0.09	-0.37	0.44	0.08	0.57	-0.27	0.49	0.30	1								
NO_3^-	0.38	-0.38	-0.32	0.20	-0.29	0.42	-0.67*	-0.13	0.70*	0.10	1							
Cl^-	-0.23	0.35	-0.18	-0.06	0.33	-0.32	0.01	-0.05	-0.36	-0.00	-0.33	1						
Pb	-0.36	0.19	-0.29	-0.39	0.37	0.42	0.30	0.81**	-0.25	0.52	-0.26	0.09	1					
Cd	-0.26	-0.30	0.06	-0.63*	0.22	-0.30	0.65*	0.15	-0.31	-0.33	-0.16	-0.45	0.22	1				
Hg	-0.41	-0.40	-0.07	-0.36	-0.36	-0.07	0.47	0.06	-0.15	-0.05	-0.04	-0.48	0.42	0.64*	1			
Zn	-0.14	-0.11	-0.33	0.46	0.00	0.12	-0.36	-0.16	0.22	0.28	-0.27	0.27	-0.01	-0.39	-0.13	1		
Cu	-0.44	-0.42	-0.58	-0.03	-0.21	0.11	0.05	-0.04	-0.00	0.06	-0.01	0.07	0.48	-0.21	0.58	0.20	1	
As	0.60	0.58	0.61	-0.29	0.38	0.24	-0.21	0.31	0. 31	-0.05	0.22	-0.20	-0.12	-0.05	-0.26	-0.24	0.71*	1

**Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at 0.01 levels (2-tailed)*

A positive correlated existed between electrical conductivity (EC) and total dissolved solids (0.67). This suggests that electrical conductivity depends on the dissolved solids and salt compounds which have the ability to furnish more number of mobile ions in solution. Sulphate ion (SO_4^{2-}) showed significant positively correlated with pH (0.72) indicating that pH increased with increase in sulphate ions. The source of sulphate ions may be from compounds of alkaline metals such as sodium, potassium and magnesium. Sulphate ion (SO_4^{2-}) had highly significant negatively correlated with COD (0.86). Nitrate ion (NO_3^-) is significantly positively correlated with SO_4^{2-} (0.70) and significant negatively correlated with COD (0.67) suggesting that this pair of anions have identical source. There was a highly significant positive association between lead (Pb) and dissolved oxygen (0.81). Cadmium (Cd) showed significant positive correlation with chemical oxygen demand and significant negative association with Total dissolved solids (0.63). Under slightly acidic to alkaline condition, lead and cadmium may have bonded to a loosely crystalline oxide. The development of a reducing condition due to microbial decomposition of organic matter promotes the reduction of lead and cadmium [38]. A significant positive association was also observed between mercury (Hg) and cadmium (0.64) suggesting that this pair of elements have identical source or chemical phenomena. Arsenic (As) had significant positive correlation with hydrogen ion concentration (0.60) and significant negative association with copper (0.71).

4. CONCLUSION

The results of this study indicated that the levels of TDS, hardness, nitrate, nitrite, chloride, copper, zinc, lead, cadmium and mercury were above the recommended limits prescribed by India, Sri-Lanka, US EPA and Philippine guideline values for inland surface water quality in most of the stations. On the other hand, values of DO, COD and BODs were below the tolerance limits while pH and concentration of arsenic were within the tolerance limits for surface water quality. The quality of this surface water is unsatisfactory for domestic, industrial, irrigation and fish culture purposes.

The general high levels of anions and heavy metals were indications of possible pollution of the sampling stations as a result of excessive application of fertilizers, manures, disposal of waste water and discharge of industrial effluents on land.

To this end, there is an urgent need for the relevant authorities to effectively control flooding promptly as they occur in order to mitigate the associated health hazards.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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