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ASSESSMENT OF WATER QUALITY STATUS AND BENTHIC FAUNA DIVERSITY OF AMUZUTA STREAM, UMUAHIA, SOUTHEAST NIGERIA

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Abstract
The assessment of water quality status and benthic fauna composition of Amuzuta Stream in Umuahia Southeastern part of Nigeria was carried in this study. Physiochemical and microbiological parameters were measured following standard procedures, and the benthic fauna's were identified accordingly. Data collected were compared to World Health Organization (WHO) standards and analyzed using one factor Analysis of variance (ANOVA). Correlation analysis was used to establish relationship between physiochemical parameters at 5% level of significance. The stream showed high bacterial and faecal load, all above the WHO limit. Benthic fauna composition and identification was carried out under a stereomicroscope and a 400X optical microscope. The benthic fauna of the stream in the dry season were dominated by Melanodies and Chronomidae (38%) followed by Veliidae, Gyrinidae, Zypoptera (6%) > Gomphidae and Hydrocarina (3%); while in the rainy season, Zygopterasp and Germidae H16 (18%) were more distributed. The ranking for remaining organisms was Hydropsychidae, Oligachaeta and Naedidae (12%)>Philopotamide, Gamphidae, Libelludae, Ecnomidae, and Caloptergidae (6%). Worms and Diptera (in dry season) and Odonata and Hemiptera (in rainy season) were the most distributed benthos. The Water Quality Index (WQI) for the stream for both seasons was calculated to be 41, and the water was found to be under excellent to good water quality for domestic use but not for drinking purpose. Further assessment of the stream water and necessary measures to be taken to prevent and reduce contamination of the water is highly recommended.

Keyword: Pollution, Water quality, Benthic invertebrate, Biodiversity, Heavy Metals

Introduction

Water is the most vital liquid in maintaining life on earth, its importance for sustenance of life cannot be overemphasized (Muhammad *et al*., 2013; Owa, 2013). It is essential for all socio-economic development and for maintaining healthy ecosystems, however, freshwater sources have experienced increased stress due to ever-rising demand and degenerate use, as well as by growing population worldwide (UN, 2006). Anthropogenic activities as well as natural occurrences have all contributed to the deterioration of water quality. Pollution poses a serious risk to life especially when the water is a source of drinking and domestic purposes for humans; polluted waters are potent agents of diseases such as cholera, typhoid and tuberculosis (Owa, 2013). Water quality control is critical in reducing the potential for explosive epidemics, as a contaminated water supply provides one of the most effective pathways for mass transmission of pathogens to a large population (WHO, 2012). Fresh water is known to be available in surface water and groundwater sources. However, as surface water becomes increasingly polluted and inadequate for some uses, people turn to groundwater for alternative supplies (Dauda, 2013). This alternative source is also becoming unsafe for human consumption due to increased rate of pollution. The pressure on the available freshwater resources in many nations of the world is accelerating and, for some, has reached "crisis levels". Macro-benthic invertebrates are useful as bio-indicators providing a more accurate understanding of changing aquatic condition than chemical and microbiological data, which at least give short-term fluctuations (Ikomi *et al.*, 2005; Idowu and Ugumba, 2005). Because of their sensitivities to different contaminants, integrated responses by their assemblages reflect the severity and nature of environmental stressors (Igborbor *et al.*, 2004). They comprise species of organisms which cut across different phyla which includes crustaceans like crayfish, molluscs such as snails, polychaetes like clam worms and aquatic insects such as aquatic wasps. Ecosystem components are so interconnected that a change in any one component of an ecosystem (biotic and abiotic) will cause subsequent changes throughout the system (Anyadiegwu and Uwazuoke, 2015). Benthic studies are a direct assessment of the environmental health of landscapes which drain into them since rivers are at a receiving end of pollution effect of land-use practices within their catchment (Igborbor *et al.*, 2004). Thus, by assessing the diversity and functional groups of the indicator species of the benthic macro-faunal communities, it is possible to evaluate water quality. The Amuzuta stream is a drinking water source for some of the residents and is not subjected to any form of direct pollution such as discharge of waste water or disposal of solid wastes but the location of the stream down a valley while residents dispose wastes on the shoulder of this valley, which is the major problem this study intends to address. Pollutants such as leachate and heavy metals could be reaching this stream indirectly through rainwater runoff and there is no doubting to the effect of even minute concentration of heavy metals on drinking water source. Thus, this study intends to objectively assess the quality of this stream water physically, chemically and biologically, as perceptions about water quality based on visual examination, taste and odour are often unreliable (Jury *et al.,* 2005;WHO, 2012).

Methodology

Study Area

This study was carried out in Amuzuta stream in Umuahia South LGA, Abia State and lies within the southeastern part of the Niger Delta Basin. The area is located between latitude 5°15` and 5°29`N, Longitude 7°27` E (Figure 1). The stream is approximately 70meters in length (which is only accessible. It is within the subequatorial climatic belt characterized by two major seasons: the wet and dry seasons. The wet season starts from April through October with peak occurrence between June and September while dry season commences in November through March annually. It has annual rainfall of 2,250mm - 2,500mm with the relative humidity of about 70-80% and mean temperature of 27°C.Umuahia has a projected population of 359,230 (Nigeria Data Portal, 2006).

Sample Collection and Analysis

Five samples were collected along the longitudinal course of the river. From where the river enters the town to where it leaves the town. The samples were labeled A, B, C, D and E (Figure 1). The water samples were collected during the dry season period (November-December) and Rainy period (April - May). At each sampling point, 5 composite samples were collected and pooled as a sample. These sampling points were at least 9 m - 12 m apart and sampling was done in morning against the water current. Clean plastic bottles were used for the collection. Measurement of physicochemical parameters was carried out using methods as outlined by APHA/AWWA/WWE (1998), parameters measured are: pH, Temperature, Electrical Conductivity, Dissolved Oxygen, Total Suspended Solids (TSS), Phosphate (PO_4^{3-}), Nitrate (NO_3^{2-}) and Heavy Metals [Sodium (Na), Potassium (K),Magnesium(Mg), Calcium (Ca), Manganese (Mn), Lead (Pb), Cadmium (Cd), Iron (Fe), Zinc (Zn), and Copper (Cu)] were determined using Perkin Elmer Analyst 400 Atomic Absorption Spectrophotometer. Microbiological samples were analyzed within 4 hours of collection by membrane filtration method to determine the total coliform per 100 ml at 37 °C and faecal coliform at 44 °C on Eosine methylene blue (EMB) agar for 24 hours, as proposed by USEPA (2002). Colonies were counted and all distinct colony types were transferred from EMB agar to trypticase soya agar (TSA) plates.

Benthic Assessment

The samplings for benthic composition were conducted during the dry and rainy periods and were collected into clean PET-bottles marked A-E, using an Eckman-Birge (225 cm^2) dredge for benthic fauna at each of the sampling sites (Figure 1). The collected samples were washed using a 300 µm mesh sieve, after which both samples were fixed with buffered 40% formalin. In the laboratory, the samples were washed using 0.125 mm mesh sieves, then sorted and identified under a stereomicroscope. The Chironomidae (Diptera) larvae were identified by a 400 X optical microscope, following the methodology used by Callisto et al. (1996). The recorded organisms were discarded.

Data Analysis and Calculations

The data were analyzed statistically using SPSS statistical software package. The appropriate mean and standard deviation were reported for the five study points. One factor Analysis of variance (ANOVA) was used for testing significant differences and correlation analysis to establish relationship between physicochemical parameters at 5 % level of significance. Contamination factor (CF), Pollution Load Index (PLI) and Water Quality Index (WQI) were calculated following these equations:

$$\mathrm{CF} = \frac{c_m}{c_b} \quad \text{…… Equation 1}$$

Where C_m is the concentration of the metal in the water and C_b is the concentration of the metal in the background. The background concentrations were taken from World Health Organization (WHO) water quality guidelines.

$$\mathrm{PLI} = (\mathrm{CF}_1\, \mathrm{XCF}_2\, \mathrm{XCF}_3 \dots\dots \mathrm{CF}_n)^{1/n} \quad \text{...Equation 2}$$

$$\mathrm{WQI} = \frac{\sum_{i=1}^{n} q_i \,.w_i}{\sum_{i=1}^{n} w_i} \quad \text{…….. Equation 3}$$

Where: Wi is weightage factor, q_i is the quality rating for the i^{th} water quality parameter

The ranking for WQI is given in Table 1 according to Verla *et al*. (2018) and Enyoh *et al*. (2018).

Results and Discussion

The results of physical, chemical and microbial parameters from the stream water in the dry and rainy season period are presented in Table 2 which is very important in the determination of its productive capacity and pollution status. Analysis of variance between mean values recorded for the two seasons were significantly different ($p > 0.05$). The difference is probably due to seasonal variations, which has been demonstrated in many studies (Kumar and Edward, 2009; Verla *et al*., 2018). From the study, rainy season was relatively higher in value than the dry season as presented in the Table below.

Results of sampling points showed that temperature of the stream ranged from 31 - 32.40 °C in the dry season while in the rainy season temperature ranged 29 - 29.8 °C. The values are within the range of 20 -30 °C set by WHO (2012), except during dry season. The result obtained in the rainy season suggests good temperature that will sustain life, encourage the invasion of alien species and biodiversity. Similar temperature has been reported for rivers in southeastern, Nigeria (Akubugwo and Duru, 2011; Duru and Kenneth, 2012; Verla *et al*., 2018). The pH value in the present study varied from 5.2 - 5.7 with mean of 5.52 during the dry season and 5.88 - 6.7 with mean of 6.32 during the rainy season. Both seasons exhibited a slightly acidic pH which wasn't in agreement to the recommended standard for pH (6.5 - 9.0) according to WHO guidelines for river water. The low pH observed during the dry season might be due to the death and decay of some aquatic life forms which releases proteins in form of ammonia. The formed ammonia dissolves in water, drastically affecting the pH and manifesting as low pH (Akubugwo and Duru, 2011). Low pH value has a tendency to increase the toxicity of most metals. Consumption of low pH water could lead to acidosis, which results in peptic ulcer (Enyoh *et al*., 2018). The reported pH was lower when compared with studies reported elsewhere in the southeast, Nigeria; 7.4 - 7.57 in dry season and 6.9 – 7.33 in wet season for Epie creek, 6.95 – 7.50 for lower Kolo creek (Aghoghoviwa and Ohimain, 2014), upper river Nun (7.17) (Seiyaboh *et al*., 2013), Nkoro River 6.8 – 8.5 (Abowei, 2012) and 6.5-7.11 for Nworie river and Verla *et al*., (2018) for Uramiriukwa river in Imo state.

The Electrical Conductivity (EC) is a measure of total dissolved salts and can greatly affect the taste of water and the acceptance of the water as potable (Pradeep, 1988). The mean EC for both seasons in the present study were low, dry season ($23.33^{\mu S/cm}$) and rainy reason ($40.2^{\mu S/cm}$) as shown in Table 2. These values were found to be within the WHO standard for safe drinking water (Table 2). The low EC could be attributed to low dissolved material in the water and thus mild anthropogenic activities. Dissolved Oxygen (DO) is the oxygen present in dissolved form in water bodies. Its reduction is greatly affected by runoff from agricultural soils containing phosphate and nitrogen compounds or the death and decay of aquatic life forms leading to the release of nitrogen compound into water body therefore causing decrease in dissolved oxygen, also known as eutrophication. According to WHO standard, the dissolved oxygen for all points during the dry season were found to be low (< 4 mg/kg) while dissolved oxygen during the rainy season was found to be slightly above standard (> 4 mg/kg) with grand mean of 4.47±1.82 mg/kg. The low DO observe during the dry season can be seen to have a relationship with low pH value ($r = 0.91$, see Table 3). This is an indication that both parameters have and are affected by similar anthropogenic activities. Similar findings were observed for some rivers in Imo state with dissolved oxygen being lower than WHO standard (Akubugwo and Duru, 2011; Duru and Kenneth, 2012; Verla *et. al*., 2018). Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) are indication of materials carried in solid and suspension respectively. In the present study, mean TDS for dry and rainy season was 3.64 and 4.41 mg/L respectively while TSS for both seasons was 4.99 mg/L (dry) and 5.33 mg/L (rainy) respectively. These values were found to be lower than the WHO standard for river water (Table 2), thereby indicating reduced pollution from runoff of soils around the area. The major cations studied were Sodium (Na), Potassium (K), Magnesium (Mg) and Calcium (Ca) with mean values of 1.41mg/L, 0.72 mg/L, 2.13 mg/L and 23.60 mg/L respectively in the dry season while in the rainy season the mean values were 2.03 mg/L, 0.73 mg/L, 2.39 mg/L, 29.54 mg/L respectively. Macro elements are elements required in relatively large quantities for the normal physiological processes of the body. Only Mg exceeded the limit set by WHO (0.5 mg/l). Calcium was the most distributed cation during the study. Seiyaboh *et al*. (2013) reported calcium levels of Orashi River ranging from 4.55 – 8.03 mg/kg in dry season and in wet season from 3.15 – 6.45 mg/kg. The concentration of magnesium was reported in the study as 3.38 – 6.86 mg/kg in dry season and 1.99 – 4.19 mg/kg values in wet season. The current study recorded high Ca and low Mg in comparison with the study of Seiyaboh *et al*. (2013) for Orashi River. However, it is similar with other reports on some rivers in south-eastern Nigeria (Akubugwo and Duru, 2011; Duru and Kenneth, 2012; Verla *et. al*., 2018). Nitrates in the present study for both seasons were all below standard when compared to the WHO standard for safe drinking water. However, highest level was recorded at sites A (0.97 mg/L) and E (0.98 mg/L) for both dry and rainy seasons. The presence of nitrate could be due to human activities such as through domestic effluents, sewage sludge, industrial discharges, leachates from refuse dumps, runoff through fertilized farmlands, leguminous soil, decayed vegetables and animal matter. This result is in conformity with the findings of Ezra and Nwankwo (2001), who further asserted that such nutrient levels lead to high nutrient productivity and favours high plankton growth. This increase was perhaps enhanced by runoffs from agricultural lands, livestock and human wastes. These nutrients result in increased amount of energy input into the water system. In the present study, phosphate level of the stream didn't exceed the limit of 5 mg/l set by WHO. Comparing the current study with others rivers in Nigeria, the phosphate levels were similar to the ones reported for rivers elsewhere, e.g Kaduna river in Kaduna (0.16 mg/L) by Agbogu et al. (2006), New Calabar River in Calabar (0.17 mg/L) by Abu and Egenonu (2008), Ogun river in Ogun state

(0.02-0.07 mg/L) by Jaji *et al.,* (2007) and for Uramiriukwa river, Imo state (0.09 mg/L) (Verla *et al.,* 2018) respectively. However, the phosphate levels could still bring an increase of nutrients within the body of water which, in turn, create plant growth as clearly seen in and around the River. Sulphate values observed were all below WHO standard for drinking water and domestic water use. Similar findings were observed in sulphate values obtained from study carried out elsewhere (Tijani *et al*., 2004; Akubugwo and Duru, 2011; Duru and Kenneth, 2012; Verla *et al*., 2018), which indicates that the water source is fresh and unpolluted. High level of sulphates in water can have adverse effects, causing diarrhea. The calcium value was higher in the dry season than the wet season. This can be due to rain water which contributes to dilution. The value for Manganese (Mn) recorded can be attributed to runoff that contains fertilizers during the flood season. Mn ranges from 0.08 -1.02 mg/L and 0.01-0.09mg/L during the dry and rainy season respectively. According to WHO standard value for Mn, all points season-wise showed low level of Mn except for point B which had the maximum level of Mn. Both Cadium (Cd) and Mn exhibited maximum values at point B, which might indicate deposition of used batteries into water body as Cd and Mn are found in batteries. The minimum and maximum levels of Zinc (Zn) observed during dry and rainy season in the present study were 2.63 and 3.62 mg/L respectively. At a taste threshold concentration of about 4mg/L, Zinc imparts an undesirable astringent taste to water (Casimir *et al*., 2015). According to FEPA (1991) standard, all points showed high values of Zn concentration. The maximum and minimum values of Iron (Fe) observed during the dry and rainy season were 0.19 mg/L, 1.097 mg/L respectively. Values obtained for Fe were all within standard as stated by WHO except for point A and B which showed values exceeding standard. The high level of Fe observed during the rainy season might be due to the fact that most mineral deposits on surrounding soil may have high level of iron, therefore runoff from deposit may contaminate the water. Lead (Pb) values obtained for both seasons were all above WHO standard for safe drinking water. Contamination of lead in river may be as a result of the dissolution of lead from the soil and earth crust. Lead (Pb) is both a toxic and non-essential metal having no nutritional value to living organisms. No amount of Pb is considered safe in drinking water. Similar study was observed in a research carried out on Mvudi River, South Africa (Joshua *et al*., 2016).

The biological characteristics such as total heterotrophic bacteria counts, total faecal count, total faecal coliform count and total coliform counts of stream Amuzuuta are presented in Table 3. The total and faecal coliform bacteria test is a primary indicator of "potability", suitability for consumption of drinking water. It measures the concentration of total coliform bacteria associated with the possible presence of disease-causing organisms (Brian, 2014). The mean concentration of total heterotrophic bacteria counts, Total fecal count, Total fecal coliform count, and total coliform counts in the water distribution were 16.08, 0.27, 0.25, and 0.25 CFU/ml respectively in the dry season while in the rainy season the distribution was 9.47, 0.06, 0.03 and 0.25 CFU/ml respectively. Overall, the results obtained were within the set limit by the WHO of 0 - 30 for total heterotrophic bacteria counts while total faecal count, total faecal coliform count, and total coliform counts were higher than the limit 0, 0, and 0 respectively set WHO. These suggest that the river is biologically polluted with fungi which could cause adverse effects on humans. The detection of high counts of total coliform and faecal coliform (*E. coli*) implies a serious health concern. According to WHO guideline, drinking water should not contain total as well as faecal coliform bacteria. Therefore, it could be said that the bacteriological quality of the stream is unacceptable and cannot be consumed. However, comparable results were reported in water of Khairpur City, Sindh, Pakistan (Abdul *et al*., 2007). Comparing the two seasons, high mean values was reported in the dry season than the rainy season, which could be due to temperature differences. At certain temperature (20 - 40 ^{o}C), microorganism is generally more active (Eszter, 2011). This temperature range is more typical for dry season period.

Correlation coefficient matrix between physical, chemical and biological characteristics at 5% significance level were carried to check for inter-relationship or association between the matrixes. The matrix of association is presented in Table 4. The coefficient simply tells us whether the sources of contamination by these pollutants and macro elements are similar or dissimilar and also how they probably influence one another (Enyoh *et al*., 2018). The use of correlation analysis has been well used by researchers in environment (Verla *et al.,* 2017; Enyoh *et al*., 2018). The rating for association or inter-relationship is based on the scale of 1 (perfect positive relationship/association), 0 (no relationship/association) and -1 (Perfect negative relationship/association). Positive or negative relationship suggests similar or dissimilar source of contamination, which can be significant or not depending on closeness to either 1 or -1 (Enyoh *et al*., 2018). A high and significant positive correlation ($p <0.05$) was observed among some of the metals, anions and physical parameters. When correlations are high between parameter in a sample, it may suggest similar contamination or pollution source(s), for instance, dumping of waste along the river channel in the area and agricultural activities. In the study, temperature correlated strongly with some metals such as Mn ($r = 0.54$) and negatively with Fe ($r = -0.58$). pH showed strong association with some metals such as Na, Fe and Pb ($r = > 0.5$). Many studies have shown that pH is an important factor that controls the behavior of ions in environmental matrix (Jing *et al*., 2007; Butler, 2009; Pérez-Esteban *et al*., 2013; Enyoh *et al*., 2018). Between metals, strong positive association was exhibited Cu and Mn ($r = 0.77$), Cu and Cd ($r = 0.84$), Cd and Mn ($r = 0.92$), Fe and Pb ($r = 0.68$), suggesting multi-element contamination for the metals. For biological characteristics, TFC correlated strongly with TCC (r = 0.64) and TFCC (r = 0.99) while TFCC and TCC had correlation coefficient of 0.63.

The degree of contamination was calculated to determine the extent and pollution status of the river. The following terminologies are used to describe the degree of contamination; Cf<6, low degree of contamination; 6≤Cf<12, moderate degree of contamination; 12≤Cf<24, considerable degree of contamination; Cf≥24, very high degree of contamination. In the present study, all sites were more contaminated in the rainy season by heavy metals (Table 5). These could be due to surface runoff during rainfall into the stream. Low contamination factor was exhibited by both Cu and Fe during the dry season whereas Cu and Mn exhibited low contamination factor during the rainy season. Cd at point A showed low contamination factor during the dry season, point B and C were very highly contaminated and point D and E were moderately and considerably contaminated respectively. During the rainy season, Cd at point A and B were very highly contaminated, point C and D had low contamination and point E was considerably contaminated. Low contamination was exhibited by Mn at point A, D and E; while point B and C were moderately contaminated during the dry season. All points for Mn during the rainy season showed low contamination. Zn for all point during the dry season exhibited a moderately contamination factor whereas during the rainy season, moderate contamination was shown at point B, D and E while point A and C were considerably contaminated. All points for season for Pb were very highly contaminated. In Table 5, Cd and Pb were conspicuous during the dry season, while Pb was conspicuous during the rainy season. Leaching of contaminated soils into water bodies is one probable source of lead pollution in the lake or river (Bordalo *et al*., 2006). The Pollution Load Index (PLI) is a potent tool in heavy metal pollution evaluation that provides a simple and comparative means for assessing the level of heavy metal pollution. The PLI represents the number of times by which the metal content in the water exceeds the average natural background concentration and gives a summative indication of the overall level of heavy metal toxicity in a particular sample. The PLI value of > 1 is polluted, <1 indicates no pollution whereas values of PLI =1 indicate heavy metal loads close to the background. Therefore, only sites A in rainy season, B in both season, C and E in dry season and D in rainy season were loaded with metal, thus polluted. This is perhaps due to numerous human activities carried out near and in the water at various locations in the river.

The WQI is a single mathematical equation that incorporates data from various water quality parameters thereby expressing the health of a water body with numbers. WQI for stream Anuuzuta at different sampling points during the dry season and rainy season are presented in Figure 2. The estimated WQI in the present study were found to be categorized under excellent to good water quality (< 50 < WQI ≤ 100, see Table 1). Similar findings were observed by Abdul *et al*., (2007), where the WQI of Dokan lake was found to be within good water quality to poor water quality from 2000 to 2009 with values 53.18 to 101.26 respectively. Due to the foregoing observation of the physiochemical parameter, it can be said that the water exhibit low level of eutrophication, owing to the high level of DO and low level of nitrate and phosphate. It could also be concluded that the water is good for domestic use due to the low level of sulphate. The general physiochemical parameter of the water is therefore in line with the low value of WQI observed and the characterization of the water as good.

Benthic fauna refers to various organisms found on (epifauna) and in (infauna) the bottom sediment. Sediment-dwelling benthic fauna can be subdivided into the main groups of mussels/snails, crustaceans, bristle worms and echinoderms. A benthic fauna assessment can indicate whether an oxygen deficiency has occurred or not at a certain place while using these organisms as water-quality bioindicators. Identification of fauna was carried out using a stereomicroscope. Chromidae (Diptera) larvae were identified by a 400x optical microscope as described by Callisto *et al.* (1996). Macro-invertebrate counts in the rainy (R) and dry (D) seasons in the bottom sediment of stream Amuzuta are presented in Figures 3(a-g). A grand total of 180 organisms were counted in the dry (81) and rainy (99) period, with total of 19 taxa found throughout the study period. The benthic fauna of the stream in the dry season were dominated by Melanodies and Chronomidae (38 %) followed by Veliidae, Gyrinidae, Zypoptera (6 %) >Gomphidae and Hydrocarina (3 %) > others (0 %) while in the rainy season Zygopterasp and Germidae H16 (18 %) were more distributed. The ranking for remaining organisms was Hydropsychidae, Oligachaeta and Naedidae (12 %) >Philopotamide, Gamphidae, Libelludae, Ecnomidae, and Caloptergidae (6 %)> Others (0 %). These suggest that worms and diptera group (in dry season) and odonata and hemiptera (in rainy season) were the most distributed group. Similarly, Oligochaeta, Chironomidae (Diptera), and the gastropod *Thiaridae Melanoidestuberculata* were reported as the most dominant groups in lower São Francisco river (northeastern Brazil) (Callisto *et. al*., 2005). High distribution of Chronomidae in stream during dry season could be due to low dissolved oxygen during the period. Chironomids have high tolerance for low oxygen conditions in sediments of freshwater ecosystems (Tudorancea *et al*., 1989) and have therefore been regarded as excellent bioindicators of poor quality waters (Hooper *et al*., 2003).

Critically looking at Figure 3 (a -g) it could be seen that species diversity declined in the middle and lower portions of the stream. At the upper and lower portions (point E and A), there was relatively high species abundance, presence of pollution sensitive families like the Dytiscidae, Hydropsychidae and Libellulidae in the streams and rivers indicating relatively better ecological conditions. However, in the middle to the lower portions (point B, C, and D), species abundance reduced along the water course. Macro-fauna in the mid and lower portions of the catchment area were typically those found in polluted waters and included the Psychodidae, Syrphidae, Chironomidae, Oligochaeta and Naedidae. Similar observation was reported for Odaw River in Ghana (Ansa *et al*., 2017). The Psychodidae are characteristic of anaerobic environments as seen in environments with decaying organic matter (low pH). The changes in the number of families and individuals along the pollution gradient corresponded to the broader categorization of the points A to E. Macro-fauna composition and abundance in this study showed that the Amuzuta stream is mildly impacted by human activities, generally showing a trend of low diversity downstream compared to high diversity upstream. As pointed by earlier author, that composition, abundance and distribution of benthic macro-invertebrates can be influenced by water quality (Hart, 1994). The reported variations in the distribution of macrobenthic organisms could be as a result of differences in the local environmental conditions. In this study, there were some seasonal changes in macro-fauna composition and abundance within sampling stations. Statistically the changes were different ($p > 0.05$), some macrofauna families showed up in the dry season but not in the rainy season and vice versa.

Conclusion

The study has successfully characterized Amuzuta stream for physiochemical and biological characteristics. The characteristics vary seasonally but generally the water was found to be of 'good quality' as revealed by the water quality index due to many physicochemical parameters conforming to the WHO standard. However, for biological characteristic, only total heterotrophic bacteria counts were within the limit while total fecal count, total fecal coliform count, and total coliform counts were higher than the limit, revealing that the water may contain some disease causing organism and thus not suitable for drinking. Furthermore, some metals (Cd and Pb) were in high concentrations, thereby having high contamination factors in dry and rainy seasons. However, the overall pollution load of metals was generally low (< 1). The possible sources of contamination were from anthropogenic origin (dumpsites and agricultural activities) as predicted by the correlation analysis with positive association exhibited by many parameters. The benthic assessment revealed that Melanodies and Chronomidae in the dry season while in the rainy season Zygopterasp and Germidae H16 were more distributed organisms. Generally, distribution varied by season and could be controlled by local environmental conditions. Finally, water from Amuzuuta stream is unsuitable for drinking, despite the good quality of the water based on WQI which is in accordance to the physiochemical parameters observed, the water was found to be contaminated with heavy metals with the most conspicuous being Pb and Cd as well as high bacterial and faecal load. The present study therefore urges that necessary steps should be taken to reduce or prevent the contamination of the water. Waste discharged into the river must be treated to meet the standard of Federal Ministry of Environment. Also, inhabitants and users who frequent the river should be enlightened about polluted state of the river and the role they will play in its remediation. Regular examination of aquatic animal such as fish should be analyzed for heavy metal bioconcentration as data obtained will expose possible health threat to human through fish consumption.

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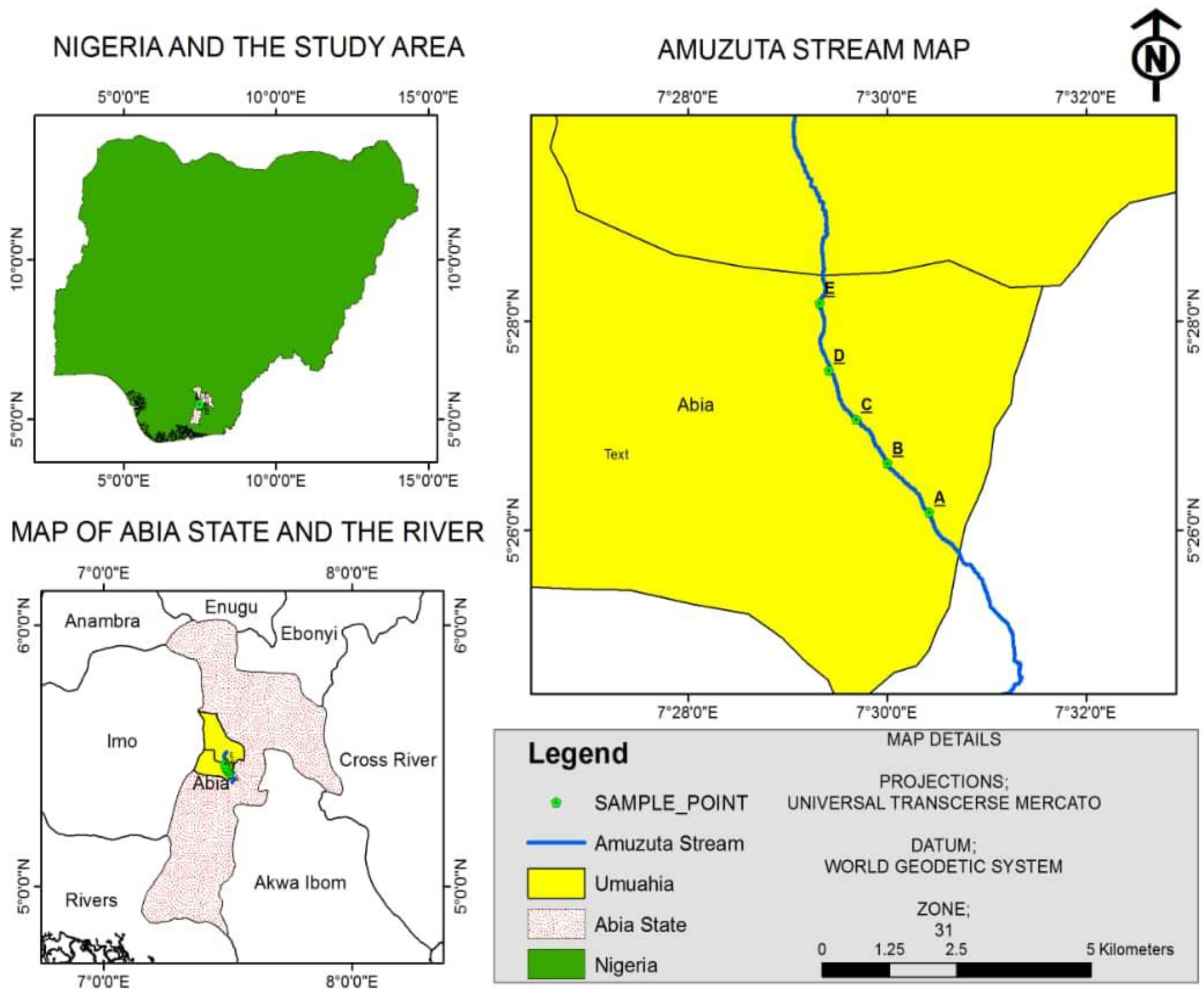

Figure 1: Map of study area showing sampling points

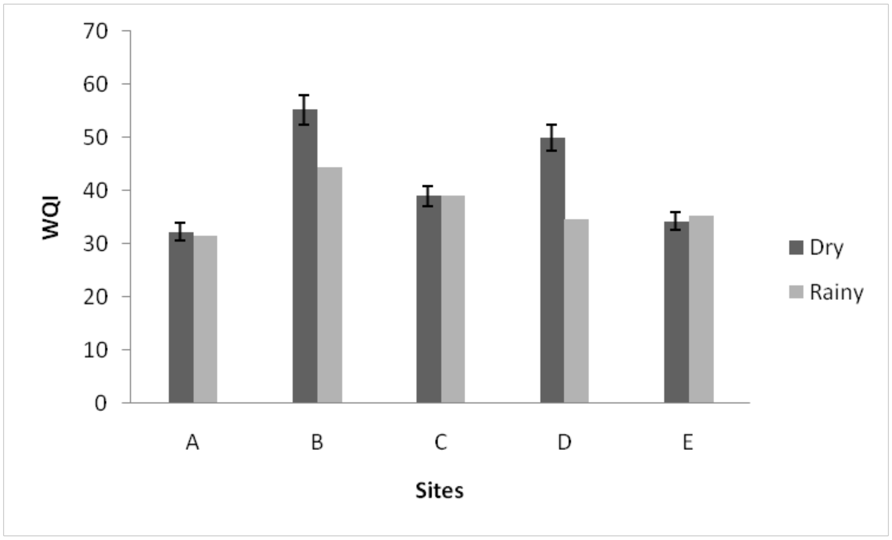

Figure 2: WQI for the different points during dry and rainy seasons

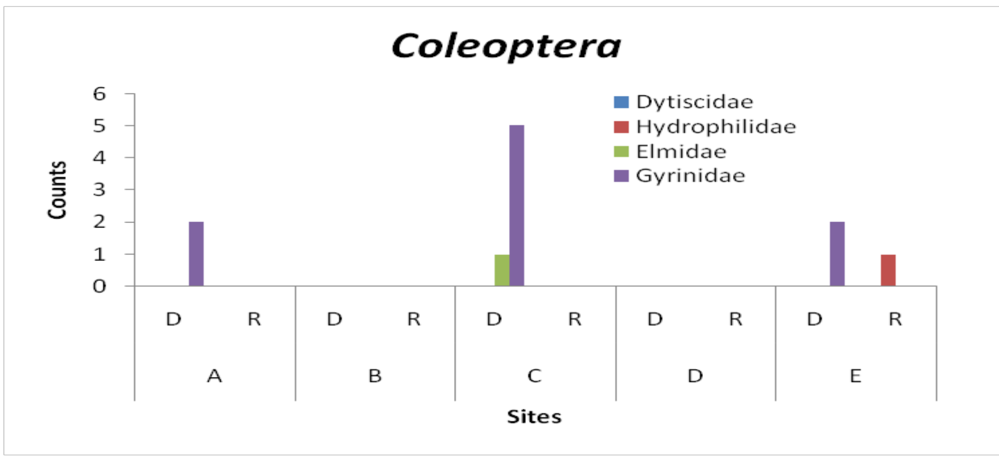

Figure 3(a): Frequency of Coleoptera distribution during the Dry and Rainy Season
****A, B, C, D, E: Sampling sites. D, R: Dry and rainy season, respectively***

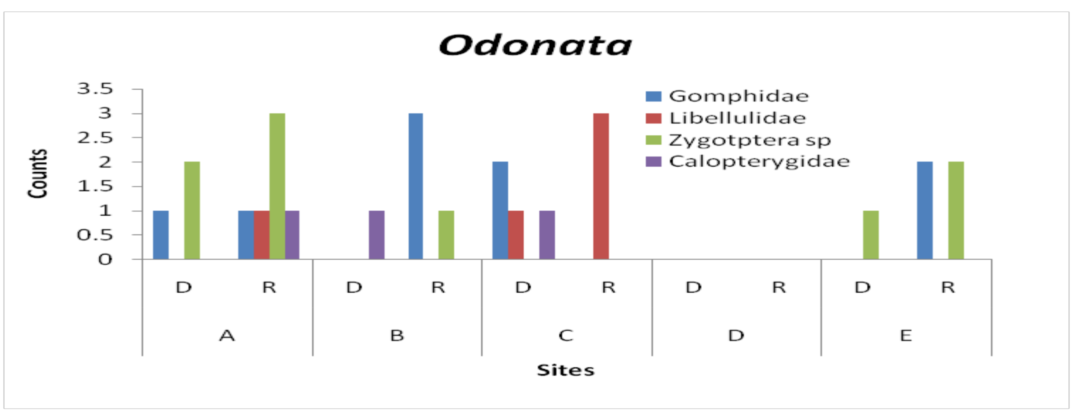

Figure 3(b): Frequency of Odonata distribution during the Dry and Rainy Season
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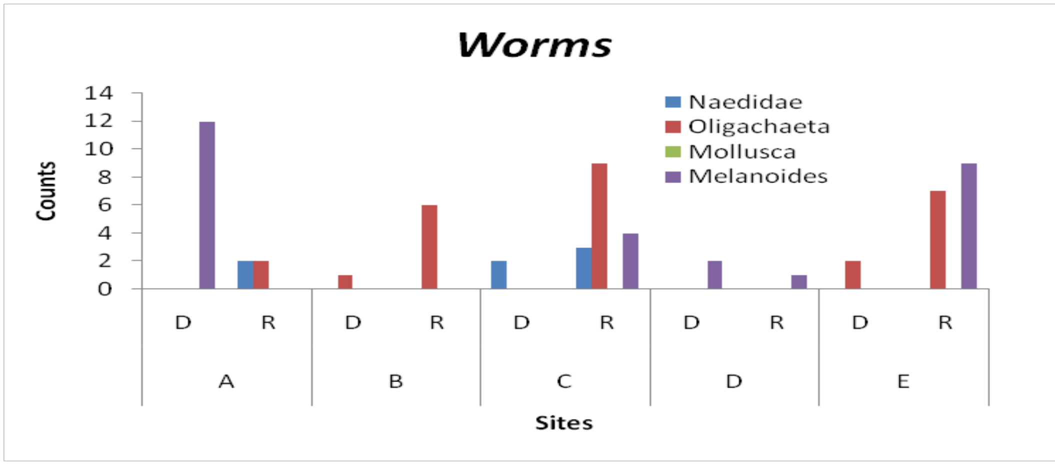

Figure 3(c): Frequency of Worms distribution during the Dry and Rainy Season
****A, B, C, D, E: Sampling sites. D, R: Dry and rainy season, respectively***

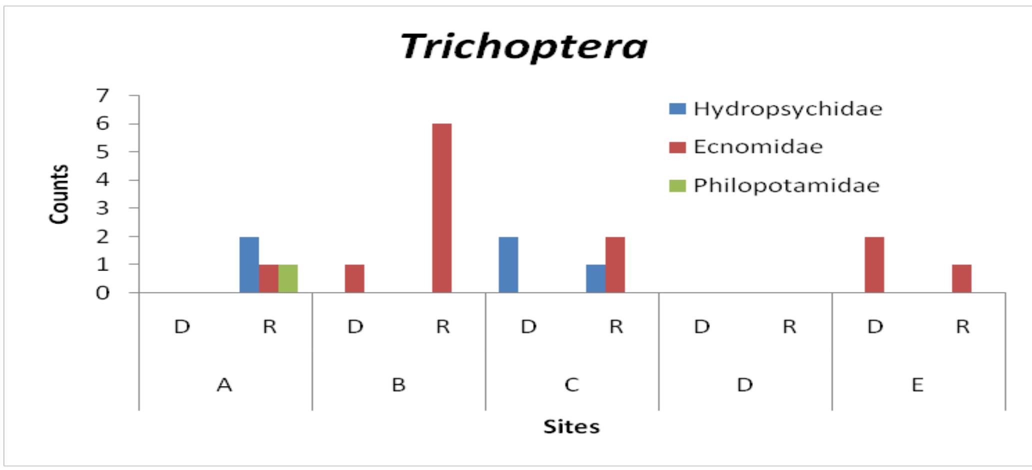

Figure 3(d): Frequency of *Trichoptera* distribution during the Dry and Rainy Season
***A, B, C, D, E: Sampling sites. D, R: Dry and rainy season, respectively**

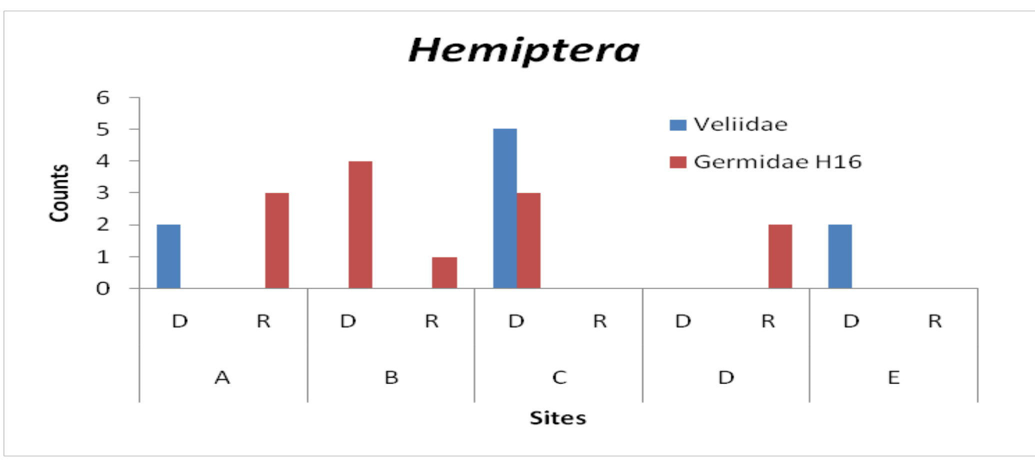

Figure 3(e): Frequency of Hemiptera distribution during the Dry and Rainy Season
****A, B, C, D, E: Sampling sites. D, R: Dry and rainy season, respectively***

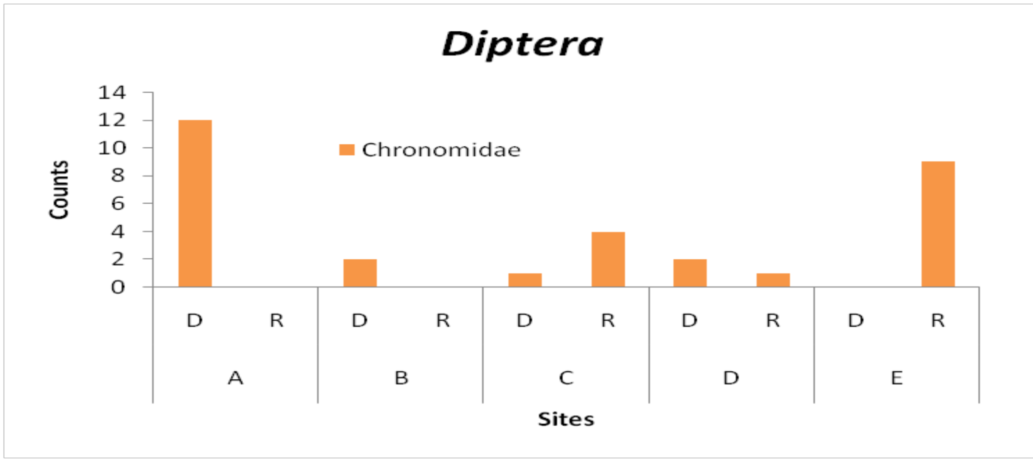

Figure 3(f): Frequency of Diptera distribution during the Dry and Rainy Season
****A, B, C, D, E: Sampling sites. D, R: Dry and rainy season, respectively***

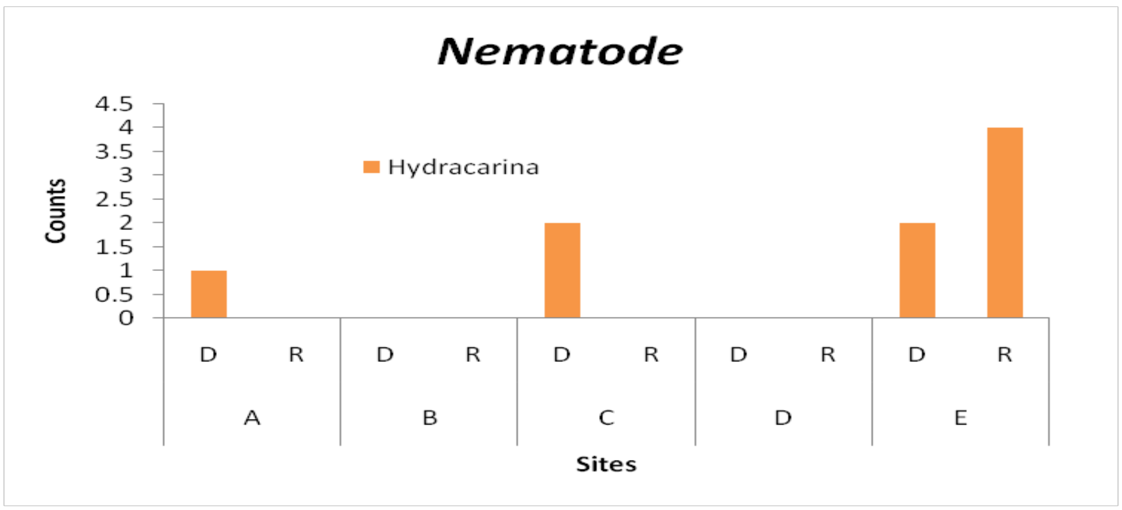

Figure 3(g): Frequency of Nematode distribution during the Dry and Rainy Season
****A, B, C, D, E: Sampling sites. D, R: Dry and rainy season, respectively***

Table 1: Water Quality Index (WQI) Rating

WQI < 50	Excellent water quality (EWQ)
50 < WQI ≤ 100	Good water quality (GWQ)
100 < WQI ≤ 200	Poor water quality (PWQ)
200 < WQI ≤ 300	Very poor water quality
WQI > 300	Unsuitable for swimming

Table 2: Mean values of physicochemical characteristics of water from Amuzuta stream during the dry and rainy season

Parameters	Dry season	Rainy season	Mean	± Std-Dev.	WHO Standard
Temperature (ºC)	31.88	29.1	30.49	±1.55	20-30
pH	5.52	6.316	5.92	±0.49	6.5-9.0
EC (µS/cm)	23.334	40.2	31.77	±12.31	100
DO (mg/kg)	2.954	5.99	4.47	±1.82	4
TDS (mg/L)	3.642	4.41	4.03	±0.73	250
TSS (mg/L)	4.998	5.334	5.17	±0.70	50
Na^+ (mg/L)	1.408	2.034	1.72	±0.39	N/A
K^+(mg/L)	0.7182	0.726	0.72	±0.58	N/A
Mg^{++}(mg/L)	2.126	2.386	2.26	±0.65	0.5
Ca^{++} (mg/L)	23.604	29.54	26.57	±8.58	70
Cu (mg/L)	0.346	0.166	0.26	±0.28	0.3
Cd (mg/L)	0.052	0.012	0.03	±0.05	0.003
Mn(mg/L)	0.412	0.042	0.23	±0.36	0.4
Zn (mg/L)	2.25	2.784	2.51	±0.71	3
Fe (mg/L)	0.136	1.032	0.58	±0.66	0.3
Pb (mg/L)	0.216	1.142	0.67	±0.85	0.01
Nitrate (mg/L)	0.924	0.846	0.88	±0.12	10
Sulphate (mg/L)	24.356	25.092	24.72	±2.46	250
Phosphate (mg/L)	1.212	1.5242	1.37	±0.48	5

EC = Electrical conductivity, DO= Dissolved oxygen, TDS= Total dissolved oxygen. TSS= Total suspended solids, Na^+= Sodium ion, K+= Potassium ion, Mg+= Magnesium ion, Ca++= Calcium ion, Cu = Copper, Cd = Cadmium, Manganese = Mn, Zinc = Zn, Iron =Fe, Lead =Pb

Table 3: Mean values of Biological Characteristics of water from Amuzuta stream during Dry and Rainy Season

Parameters	Dry season	Rainy season	Mean	± Std-Dev.	WHO Standard
THBC	16.084	9.466	12.78	±06.58	0-30
TFC	0.268	0.058	0.16	±0.38	0
TFCC	0.252	0.03	0.14	±0.34	0
TCC	0.254	0.252	0.25	±0.42	0

THBC-Total heterotrophic Bacterial Count, TFC-Total Fungi Count, TFCC-Total Feacal Coliform Count, TCC-Total Coliform Count

Table 4: Correlation matrix between physical, chemical and biological properties

	Temp	pH	EC	DO	TDS	TSS	Na	K	Mg	Ca	Cu	Cd	Mn	Zn	Fe	Pb	NO_3^-	SO_4^{2-}	PO_4^{2-}	THBC	TFC	TFCC	TCC
Temp	1																						
pH	**-0.75**	1																					
EC	**-0.64**	**0.56**	1																				
DO	**-0.75**	**0.91**	**0.78**	1																			
TDS	-0.48	0.41	0.33	0.28	1																		
TSS	-0.25	0.12	0.35	0.14	0.44	1																	
Na^+	**-0.75**	**0.80**	**0.83**	**0.84**	**0.52**	0.46	1																
K^+	-0.21	-0.12	0.50	0.03	-0.18	0.17	0.20	1															
Mg^{++}	-0.02	**0.52**	0.16	0.42	0.37	0.42	0.44	-0.38	1														
Ca^{++}	-0.30	0.36	-0.20	0.12	**0.51**	0.13	0.29	**-0.64**	0.29	1													
Cu	0.36	-0.23	0.23	-0.16	-0.08	**0.58**	0.12	0.47	0.34	-0.39	1												
Cd	0.41	-0.27	-0.06	-0.29	-0.06	**0.68**	-0.02	0.15	0.34	-0.15	**0.84**	1											
Mn	**0.54**	-0.38	-0.28	-0.48	-0.21	0.44	-0.27	0.11	0.20	-0.14	**0.77**	**0.92**	1										
Zn	-0.47	0.41	0.46	**0.52**	-0.29	**-0.52**	0.32	0.45	-0.35	-0.28	-0.34	**-0.63**	**-0.62**	1									
Fe	**-0.58**	**0.51**	0.48	**0.51**	**0.86**	0.42	**0.59**	-0.28	0.43	0.48	-0.17	-0.22	-0.38	-0.19	1								
Pb	-0.49	**0.53**	**0.73**	**0.58**	**0.58**	0.35	**0.82**	0.24	0.44	0.25	0.27	-0.08	-0.24	0.19	**0.65**	1							
NO_3^-	**0.50**	-0.05	-0.02	-0.05	0.19	-0.04	-0.04	-0.19	**0.59**	-0.21	0.37	0.18	0.11	-0.27	0.09	0.23	1						
SO_4^{2-}	0.04	**0.55**	0.16	0.47	0.13	-0.29	0.30	-0.30	**0.55**	0.03	-0.04	-0.09	-0.16	0.23	0.04	0.19	**0.63**	1					
PO_4^{2-}	-0.21	0.36	0.34	0.38	-0.05	0.21	0.53	-0.04	0.11	0.39	0.17	0.25	0.19	0.14	0.01	0.30	-0.31	0.14	1				
THBC	**0.62**	**-0.51**	**-0.50**	-0.48	-0.12	0.28	-0.34	-0.48	0.30	0.21	0.26	0.41	0.36	**-0.72**	-0.05	-0.16	0.32	-0.21	-0.04	1			
TFC	0.32	-0.44	-0.16	-0.37	0.02	-0.41	-0.32	-0.02	**-0.54**	-0.16	-0.25	-0.19	-0.20	0.06	-0.22	-0.28	0.16	0.13	-0.09	-0.07	1		
TFCC	0.37	-0.49	-0.16	-0.42	-0.02	-0.41	-0.35	0.02	**-0.57**	-0.17	-0.17	-0.14	-0.11	0.04	-0.26	-0.27	0.14	0.08	-0.03	-0.06	**0.99**	1	
TCC	0.03	-0.39	-0.13	-0.35	0.47	0.07	-0.21	-0.27	-0.39	0.25	-0.31	-0.14	-0.18	-0.40	0.38	-0.12	-0.08	-0.34	-0.16	0.18	**0.64**	**0.63**	1

Numbers in bold are significant at 0.05

Table 5: Computed Metal Contamination Factors and Pollution Load Index (PLI) for each Site during Dry (D) and Rainy (R) Season

Metals	**Contamination factors**									
	A		**B**		**C**		**D**		**E**	
	D	***R***	***D***	***R***	***D***	***R***	***D***	***R***	***D***	***R***
Cu	0.38	2.03	2.63	0.70	0.77	0	0.50	0	0.43	0.03
Cd	0	10	60	6.67	23.33	0	0	0	3.33	3.33
Mn	0.2	0.05	2.55	0.2	1.95	0.23	0.23	0.03	0.23	0.03
Pb	13	231	18	206	52	12	12	107	13	15
Zn	0.87	1.11	0.4	0.80	0.74	1.21	0.87	0.53	0.81	0.89
Fe	0.33	3.66	0.63	3.66	0.63	0.07	0.33	6.57	0.33	0.32
PLI	0.81	3.14	3.50	2.88	3.08	0.78	0.86	1.50	1.02	0.48

Keywords: A, B, C, D and E are sampling points along the stream course