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Impacts of Agrochemical on Water Quality and Macroinvertebrates Abundance and Distribution in Ikpe Ikot Nkon River, South-South, Nigeria

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Abstract: A study on the impacts of agrochemicals on macro-invertebrate's abundance and distribution in Ikpe Ikot Nkon River was carried out between October, 2016 and September, 2017. Surface water and macro-invertebrate's samples were collected monthly from three sampling stations along the river course. Macro-invertebrates were collected using a standard hand net of 0.5mm mesh size for samples within the water column while van-veen grab sampler of 0.5m^2 surface area was used for collection of macro-benthos. Water samples were collected using water sampling bottles (1liter). Sample identification and analysis were achieved using standard identification guide and laboratory procedures. The range value of surface water temperature was 27.52-27.59 ^{0}C, EC 7.96-16.69 µs/cm, pH 6.58-6.79, DO 2.36-6.87 mg/L, TDS 10.53-17.88 mg/L, BOD 2.07-6.45 mg/L, COD 134.20-298.83 mg/L, Alkalinity 62.95-86.33 mg/L, phosphate 1.77-4.78 mg/L, Nitrate 3.40-6.82 mg/L and chloride 15.94-31.01 mg/L. The abundance of macro-invertebrates and the physicochemical parameters at the various stations were significantly different ($p<0.05$). A total number of 27 species comprising of a total number of 747 individuals', belonging to 3 phyla and six (6) classes were identified across the stations. Phylum Arthropoda were the most abundance accounting for 75.78%, followed by Annelida and Mollusca with relative abundance of 16.46% and 7.76% respectively. Higher macro-invertebrates were identified in station 1 (336) individual followed by station 3 (210) and station 2 had the least (201) with relative abundance of 44.98 %, 28.12 % and 26.90 % respectively. From the investigation of findings in the present study it is believed that the river is impacted with agrochemicals which comes into the river via surface run-off. This stem from the low values of DO and high values of nitrate, phosphate and COD recorded in station 2 and 3 which are closed to agricultural farmlands with extensive use of agrochemicals for pest control and high yield of crops. In terms of macro-invertebrate's abundance station 2 and 3 had the least when compared to station 1 which was sited far from where there are no farmlands and serves has the control. Based on the findings of this study it is evident that agrochemical have impact on water quality and macro-invertebrate's abundance and distribution in the study area. This study recommends the use of agrochemicals at low concentrations and ridges should be built around farmlands to prevent surface run-off during heavy precipitation.
[Jonah, UE, George, UU, Avoaja, DA. **Impacts of Agrochemical On Water Quality and Macroinvertebrates Abundance and Distribution in Ikpe Ikot Nkon River, Southern, Nigeria.** *Nat Sci* 2020;18(5):42-49]. ISSN 1545-0740 (print); ISSN 2375-7167 (online). http://www.sciencepub.net/nature. 7. doi:10.7537/marsnsj180520.07.

Keywords: Agrochemicals; Impacts; Water Quality; Macro-Invertebrates; Abundance; Distribution

1. Introduction

Agrochemicals are widely acknowledged as one of the most anthropogenic pollutant of aquatic ecosystems, with a wide range of impacts on aquatic organisms. Modern development and agricultural intensification have increased the concentration of both organic and inorganic wastes in the water bodies. At the same time, increased in human population growth, cities expansion and high demand of food has also contributed to higher loads of pollutants entering the water as a result of exorbitant use or misuse of agricultural inputs like pesticide and fertilizers to increase food productivity. These pollutants get into the water body through surface run-off, which will result in alteration of the physical, biological and chemical properties of water; either by increasing or decreasing the water quality parameters, which in turn affect the resident macro-invertebrate's fauna.

Studies on macro-invertebrates have been reported by several authors; Andem*et al.* (2015) reported that agrochemicals influenced the survival and distribution of benthic dwelling macro-invertebrates of Afi River, Nigeria. According to Caryn (2010), macro-invertebrates are threatened by changes in their habitat structure which is associated with pollution, erosion and siltation. They are also sensitive to some level of organic pollution and variations in water quality parameters like dissolved oxygen, pH, salinity, temperature, turbidity and biochemical oxygen demand (BOD) as reported by water and Rivers Commission (2001).

Aquatic macro-invertebrates play a vital role in water body development and management. They serve as bio-indicators in water quality, provide accurate understanding of changes in water quality parameters and constitute a vital link in aquatic food chain (energy flows). However, the use of chemical substances in agriculture to mitigate the abundance of plant pest and also to increase food productivity have resulted in the indiscriminate use of these agrochemicals at high concentrations. These substances find their way into the aquatic ecosystem through surface run-off altering the biodiversity and distribution of most aquatic species. The case is not different in Ikpe Ikot Nkon River where the surrounding land mass has been subjected to domestic and various agricultural activities. Therefore, this study was aimed to ascertain the levels at which agrochemicals affects the abundance and distribution of macro-invertebrate's fauna of Ikpe Ikot Nkon River.

2. Material and Methods

2.1 Description of the study area

Ikpe Ikot Nkon River is located in Ini Local Government Area, Akwa Ibom State, South-South, Nigeria, between Latitude 5^0 24.0'' 59.0' N and Longitude of 7^0 46''55.7 E (Figure 1). The River flows in a North-West direction from its source at Nkari River to NkanaIkpe River and emptied into Eniong River in Cross River State. The flood plains are fertile for agricultural activities, and the river received allochtonous inputs of agrochemicals of anthropogenic sources through surface run-off from the surrounding agricultural farm land. The river serves as source of water for irrigation and domestic purposes for the inhabitants of the area.

2.2 Sampling Stations

Three sampling stations were chosen for this study: **Station 1** – 1km from the head bridge, no human activities are carried out exception of fishing at this station, the area is shaded by riparian vegetation and is also characterize by high water current velocity. **Station 2** – 2km downstream away from station one, it's characterized by slow water current velocity. Human activities here include sand dredging, car wash and agricultural activities were agrochemicals are used extensively. **Station 3** – 2km downstream away from station two. This area is characterized by minimum exposure to wastes ranging from domestic and agricultural waste, slow water current, run-off is high and the substratum is muddy (Fig.1).

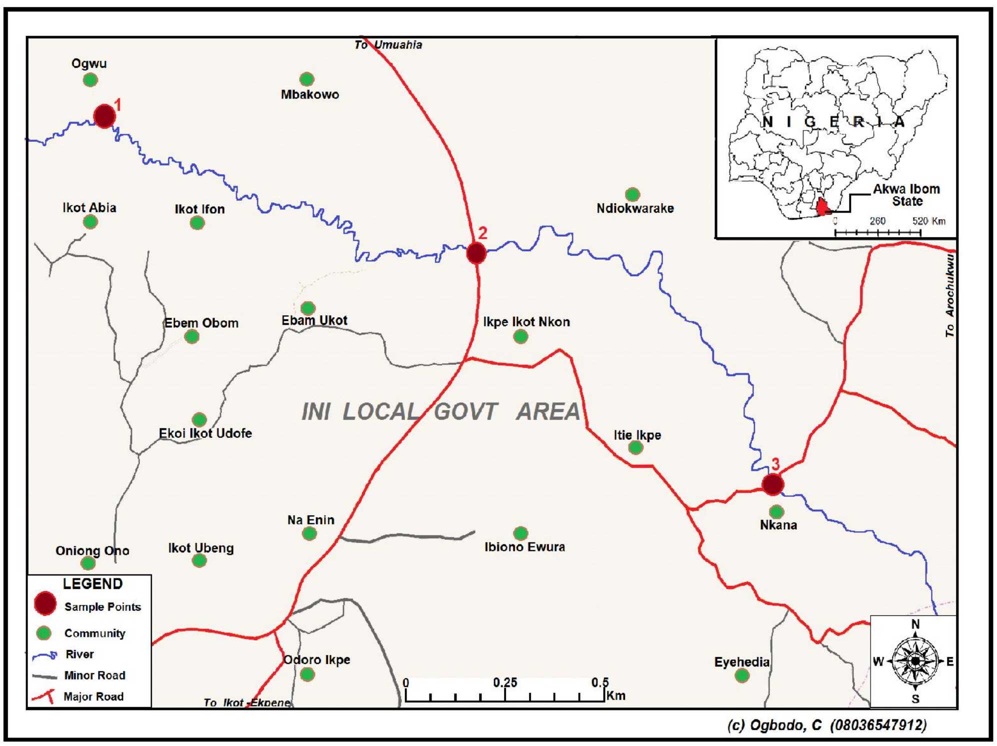

Figure 1: Map of the Study Area Showing the Sampling Stations

2.3 SamplesCollection and Analysis

2.3.1 Collection of Water Samples and Analysis

Water samples were collected in each of the sampling stations from October, 2016 to September 2017. At all times sampling was carried out between 08:00 am and 12:00 noon each sampling day. Water samples were collected at the depth below 30cm on monthly basis with 1litre water sampler and stored in sterilized 1 litre plastic bottles. Water samples for temperature, electrical conductivity (EC), hydrogen ion concentration (pH), dissolved oxygen (DO) and Total dissolve solids (TDS) were determined *in situ* using pH / EC / TDS / Temperature combined HANNA, HI 991301 Model instrument while DO was determine using digital portable analyzer JPB - 607A from "Search Tech Instrument (USEPA, 2009). Water sample for biological oxygen demand, chemical oxygen demand, phosphate, nitrate, chloride and alkalinity were collected using 250 ml glass bottle. The sample bottle was filled with water and stopped under water, ensuring that no air bubble was trap in it. After collection, all samples were stored in ice-chest coolers and transported to the laboratory (Ministry of Science and Technology Laboratory, Uyo). In the laboratory samples were determine according to Standard Methods for Examination of Water and Waste water (APHA, 2005; AOAC, 2000).

2.3.2 Collection of Macro-invertebrates

Macro-invertebrate's samples were collected with a standard hand net of 0.5mm mesh size for samples within the water column while Van-veen grab sampler of 0.5m^2 surface area was used to collect macro-benthos from each of the sampling stations. The net was placed in a water column facing upstream based on the flowing direction of the river and the water were disturbed upstream using legs and water sample was collected with the aid of the hand net in each of the station. Sediment samples from each station collected with the aid of a Van-veen grab sampler were emptied into polythene bag with little water and sieved with mesh size nets of 2mm, 1mm and 0.5mm in order to remove the clay particles. The residual retained on the screens of the sieves were washed into a white shallow enamel tray with moderate volume of water to improve visibility for sorting. Sorted samples were preserved in 4% formaldehyde in small glass jars. The individual macro-invertebrates were identified macroscopically using the guides of ward and Whipple (1959), Edmondson (1959), Willoughby (1976) and Pennak (1978). The numbers of macro-invertebrates isolated were counted based on the phylum, classes in each of the respective stations.

2.4 Data Analysis

Statistical package for Social Sciences (SPSS) version 20 was employed to compute Mean, variance and standard error in the data. Also, two-way analysis of variance (ANOVA) and Least Significant Difference (LSD) test were employed to separate significant differences in mean values computed for stations. The probability level was set at $p = 0.05$. Diversity indices of macro-invertebrates were calculated using Shannon-wiener diversity index (H), margalef's index (d) for species richness and pielou evenness index (E) for species equitability or evenness. All calculations of diversity indices were made using PAST (Paleontological Statistics, Version 3.0) software.

3. Results

3.1 Physicochemical parameters

The mean, standard error, and range of the physico-chemical parameters of Ikpe Ikot Nkon River obtained during the study period are shown in Table 1. The temperature values valid slightly across the stations; ranging from 25.0-30.0 ^{0}C. Highest value with mean of 27.59 ^{0}C was recorded in station 1, while station 3 had the least mean value of 27.25^{0}C. The values were not significantly different across the stations at $p>0.05$.

EC values was higher at station 2 with a mean value of 16.69 µs/cm, while station 1 had the least mean value of 7.96 µs/cm. EC values obtained were significant between station 1 and 2 and station 1 and 3 at $p<0.05$.

pH values ranged between 6.1 and 8.1 mg/L, higher mean value of 6.79 was obtained in station 1, while station 3 recorded the lowest mean value of 6.58. The values were not significantly different across the stations at $p>0.05$.

DO mean value was also higher at station 1 (6.87mg/L), station 2 and 3 had lower values of 2.36 and 2.38 mg/L respectively. DO values obtain were significant between station 1 and 2 and station 1 and 3 at $p<0.05$.

TDS had it's ranged between 8.0 and 34.1 mg/L, higher mean value of 17.88 mg/L were recorded in station 2. The values obtain were significant between station 1 and 3 and station 2 and 3 at $p<0.05$.

Lowest mean BOD value was recorded in station 1 (2.07 mg/L), while the highest were obtained in station 2 and 3 (6.45 and 6.37mg/L) respectively. The values were significantly difference between station 1 and 2 and 1 and 3 at $p<0.05$ respectively.

Similar results were recorded for COD with the mean highest value recorded at station 2 and 3, while the lowest value was recorded at station 1. The values obtained were significantly difference between station 1 and 2 and 1 and 3 at $p<0.05$ respectively.

Phosphate and Nitrate values were highest at station 2 with mean value of 4.74 and 6.82mg/L, while station 1 had the lowest mean value of 1.77 mg/L and 3.40mg/L respectively. There was significant difference between station 1 and 2 and 1 and 3 at $p<0.05$.

Chloride mean value was high in station 2 and the lowest mean value was recorded in station 1. There was significant difference between station 1 and 2 and 1 and 3 at $p<0.05$.

Total Alkalinity showed a progressive increase from station 1 to 3, but the highest value was obtained at station 3 (86.33 mg/L), while the lowest was in station 1(62.95mg/L). There was significant difference between station 1 and 2 and 1 and 3 at $p<0.05$.

Table 1: The mean, standard error and range of physico-chemical parameters of Ikpe Ikot Nkon River during the study period (October, 2016 – September, 2017).

PARAMETERS	STATION 1	STATION 2	STATION 3
Temperature (^{0}c)	$27.59^a \pm 0.45$(25.0-30.0)	$27.53^a \pm 0.44$(25.1-30.0)	$27.25^a \pm 0.45$(25.0-30.0)
EC (µs/cm)	$7.96^a \pm 0.51$(5.1-11.2)	$16.69^b \pm 2.01$(9.0-31.0)	$15.98^b \pm 1.93$(8.2-28.0)
pH	$6.79^a \pm 0.04$(6.5-7.0)	$6.70^a \pm 0.15$(6.2-8.1)	$6.58^a \pm 0.15$(6.1-7.8)
DO (mg/L)	$6.87^a \pm 0.47$(5.2-10.8)	$2.36^b \pm 0.43$(2.1-6.9)	$2.38^b \pm 0.35$(2.3-6.2)
TDS (mg/L)	$10.53^a \pm 0.37$(8.0-12.2)	$17.88^a \pm 1.92$(12.0-32.4)	$16.50^b \pm 1.85$(11.0-34.1)
BOD (mg/L)	$2.07^a \pm 0.16$(0.9-2.8)	$6.37^b \pm 0.23$(2.3-4.9)	$6.45^b \pm 0.22$(2.5-4.9)
COD (mg/L)	$134.20^a \pm 6.24$(108.8-172.2)	$298.84^b \pm 23.37$(322.8-139.2)	$272.30^b \pm 19.52$(336.0-144.0)
Phosphate (mg/L)	$1.77^a \pm 0.23$(0.72-2.90)	$4.74^b \pm 0.33$(2.40-5.00)	$3.34^b \pm 0.21$(2.60-4.95)
Nitrate (mg/L)	$3.40^a \pm 0.37$(2.10-5.70)	$6.82^b \pm 0.53$(4.38-10.30)	$5.58^b \pm 0.39$(4.18-9.24)
Chloride (mg/L)	$15.94^a \pm 0.77$(11.36-21.30)	$31.01^b \pm 4.46$(19.81-82.36)	$22.17^b \pm 4.5$(18.22-77.34)
Alkalinity (mg/L)	$62.95^a \pm 3.02$(45.00-78.00)	$84.58^b \pm 5.57$(53.00-118.00)	$86.33^b \pm 6.67$(50.00-118.00)

$\pm$ = standard error. Means with different superscript in the same row indicate significant difference ($p<0.05$).

3.2 Macro-invertebrate's composition

The composition and relative abundance of macro-invertebrates encountered in Ikpe Ikot Nkon River during the study period is presented in Table 2, while diversity indices of macro-invertebrates are presented in Table 3. A total number of 27 species comprising of a total number of 747 individuals', belonging to 3 phyla and six (6) classes were identified. The phylum Arthropoda was the most abundance and accounted for about 75.78%, followed by Annelida which accounted for 16.46%, while mollusca accounted for 7.76% of the total number of macro-invertebrate's encountered during the study.

Station 1 had the highest number of individual's species with a total of 336 which accounted for about 44.98%, followed by station 3 (210) individuals accounted for 28.12%, while station 2 had the least number of individuals of 201, accounted for 26.90% of the total number of macro-invertebrate's encountered during the study in each of the station.

Diversity indices show that Shannon-Wiener (H) were ranged between 2.742 and 2.993. Station 1 recorded the highest value of 2.993 followed by station 3 (2.782), while station 2 had the least value of 2.742. Margalef index (d) had its highest value at station 1 (3.962) while station 2 recorded the least value of 3.339. Evenness index (E) obtained spatially were high with the highest value in station 1 (0.944) and least value in station 2 (0.864).

Table 2: Composition and Relative abundance of Macro-Invertebrates Abundance in Ikpe Ikot Nkon River during the period of study (October 2016 - September 2017).

TAXA	ST 1	ST 2	ST 3	TOTAL	RA%
PHYLUM: ARTHROPODA					
Class: Insecta					
Chironomus larvae	-	20	20	40	5.35
Chironomus plumosus	-	18	27	45	6.02
Damselfly nymph	12	4	4	20	2.68
Macromiasplendens	9	2	6	17	2.28
Aquarius remigis	39	18	23	80	10.70
Corixa punctate	17	9	15	41	5.49
Microveliaumbricola	9	3	4	16	2.14
Valia caprai	8	1	3	12	1.60
Hydrophilussp	13	3	6	22	2.95
Cybisterfimbriolatus	16	7	5	28	3.75
Isoperla ornate	21	2	-	23	3.08
Sialislutaria	34	2	1	37	4.96
Callibaetispictus	5	1	-	6	0.80
Baetiscalaurentina	23	-	-	23	3.08
Baetiscaobesa	15	-	-	15	2.0
Hydropsychepellucidula	19	-	-	19	2.55
Helicopsychesp	11	-	-	11	1.48
Class: Crustacean					
Astacuspallipes	18	20	11	49	6.56
Homarinuscapensis	16	6	6	28	3.75
Sudunonaultes africanus	6	3	4	13	1.74
Class: Arachnida					
Argyronetaaquatica	11	5	5	21	2.82
Total	**302**	**124**	**140**	**566**	**75.78**
PHYLUM: MOLLUSCA					
Class: Gastropoda					
Pomacea canaliculated	7	5	10	22	2.94
P. maculate	3	1	4	8	1.07
Class: Bivalvia					
Anodonta anatine	7	5	8	20	2.68
Total	**19**	**16**	**23**	**58**	**7.76**
PHYLUM: ANNELIDA					
Class: Clitellata					
Limnodrilushoffmeisteri	-	24	16	40	5.35
Tubifex fubifex	-	30	26	56	7.49
Lumbricusterrestris	15	7	5	27	3.62
Total	**15**	**61**	**47**	**123**	**16.46**
Total no. of individual	336 (44.98%)	201 (26.90%)	210 (28.12%)	747 (100%)	

Table 3: Diversity indices of macro-invertebrates during the study Period (October, 2016 – September, 2017).

Indices	Station 1	Station 2	Station 3
No. of Species	23	23	21
Individuals	336	201	210
Shannon (H)	2.993	2.742	2.782
Margalef (d)	3.962	3.339	3.386
Evenness (E)	0.944	0.864	0.9003

4.0 Discussion

Water quality is a determinant factor influencing the growth and abundance of macroinvertebrates fauna. The range of water temperature values obtained in this study corroborates with the reports of Okarafor*et al*. (2013) for calabar River and George and Atakpa (2015) for Cross River Estuary. Slight fluctuations in temperature values observed spatially could be attributed to the location and time of sampling.

High EC values in station 2 and 3 during the study period could be attributed to the presence of inorganic dissolved salts in these stations brought in through surface run-off from adjourning lands. Low values of this parameter in station 1 could be an indication of inactive deposition of these factors into the station indicating less perturbations.

The pH values obtained during this study across the stations are within the range reported by Zakariya *et al.* (2013) in Lower Niger River and Esenowo *et al*. (2017) for Nwaniba River, Nigeria. The values recorded were within the recommended range for aquatic life by WHO (2011).

The low values of dissolved oxygen (DO) recorded in station 2 and 3 may be as a result of inorganic and organic wastes discharge either directly or indirectly in those stations from varying anthropogenic sources. These wastes must have expedited an increase in the rate of microbial degradation. Therefore, waste degradation and decomposition by micro-organisms could have contributed to the reduced dissolved oxygen values, noticeable in station 2 and 3. High value of this parameter in station 1 could be an indication of reduced amount of organic and inorganic wastes, which could have used much of DO for decomposition. Anago *et al.* (2013) affirmed that the depression in DO level could be due to chemical and biological oxidation processes in the water.

Total dissolved solid (TDS) is a measure of the total ionic concentration in the water body. Higher mean values of TDS and alkalinity in station 2 and 3 may be linked to the discharge of allochthonous substance into these stations. It could also be attributed to the positive effect of rainfall which leads to subsequent runoffs of nutrients such as nitrate, phosphate and salt-rich (sodium chloride) substance from inundated lands into these stations. Akpan (2004) affirmed that increased precipitation and subsequent runoffs from the surrounding lands increased the TDS values of a water body.

Biochemical oxygen demand (BOD) values obtained in this study were also higher in station 2 and 3 and low in station 1. This may be linked to the consistent discharge of organic wastes into these stations (2 and 3) which usurp dissolved oxygen in large amount by micro-organisms for their decomposition and degradation. Low value of BOD in station 1 is an indication of low organic concentration that would have required a high amount of dissolved oxygen for biodegradation of this waste.

Chemical oxygen demand (COD) values were also higher in station 2 and 3 than in station 1. This may be interpreted to imply that these stations had high organic-rich wastes which were oxidized chemically. The low COD in station 1 may mean that this station were devoid of substantial waste substance emanating from anthropogenic perturbation.

High phosphate and nitrate values were obtained spatially in station 3 and 2 when compared with station 1. This may be attributed to the consistent used of inorganic fertilizer rich in phosphate and nitrate in the surrounding agricultural farm lands in these stations. These nutrients get into the river at these stations through surface runoff, thereby resulting in the overgrowth of aquatic plants which in turn lead to eutrophication and depletion of dissolved oxygen. This assertion is supported by the report of Commins *et al.* (1983) that high nitrate and phosphate concentration in the river may be related to inputs from agricultural farm lands. Ufodike *et al.* (2001) made similar observations for Dokowa Mine Lake. Kennedy and Hains (2002) also reported that nitrate increase with surface runoff and at deeper depths.

The higher value of chloride concentrations recorded in station 2 may be attributed to domestic activities ranging from the use of chemical (detergent) and other substance rich in chloride salts deposited in this station.

The findings of the present study revealed that the physico-chemical characteristics have influenced on the abundance and distribution of aquatic macro-invertebrates. The 27 species (taxa) of macro-invertebrates recorded in this study is consistent with the earlier assertion by Ezekiel *et al.* (2011) in Sombreiro River, Nigeria and higher when compared with the values reported by Adjarho *et al.* (2013) from Ona River, Ibadan. Of the six classes of macro-invertebrates recorded in this study, the class insecta dominated with species richness of seventeen (17), the class Arachnida and Bivalvia had the least species richness of one (1).

High macro-invertebrate's species obtained in station 1 may be attributed to the low degree of organic and inorganic wastes discharge when compared to other stations. Also, this station is devoid from anthropogenic impacts ranging from sand dredging and disturbance of riparian zone. Low species of macro-inervetebrates recorded in station 2 and 3 may be attributed to some physiological stress imposed on these stations. This agree with the reports of Andem *et al.* (2012) for Ona River, where they recorded high macro-invertebrates in an area devoid from anthropogenic impacts. The dominance of insecta across the sampling stations may be attributed to their ubiquitous nature, and the conspicuous absence of *Baetiscalaurentina, Baetiscaobesa, Hydropsychepellucidula and Helicopsyche* species at station 2 and 3 may be attributed to exorbitant farming activities at the bank of the river which lead to extensive leached of organic and inorganic waste through surface runoff into these stations. The presence of high load of organic and inorganic wastes allows for proliferation of aquatic plant resulting in eutrophication. The process of eutrophication leads to reduction of dissolved oxygen level at these stations which in turn affect the distribution and abundance of non-tolerance species.

The occurrence of gastropoda *Pomaceacanaliculata* and *P. maculata* can be traced to their tolerance to some level of organic pollution. This agree with the reports of Aina and Oyebamiji (2011), who reported the occurrence of *Balinusforskalii* in area influenced by domestic wastes discharge. The abundance of *Limnodrilushoffmeisteri* and *Tubifex tubifex*in station 2 and 3 is an indication of pollution, deteriorating water quality and their ability to tolerate alkaline and anoxic condition of the environment. This is in agreement with the reports of Sharma and Chowdhary (2011), who reported the occurrence of *Tubifex tubifex* and *Limnodrillus sp.* at sites where human pressure and pollution were predominant.

Biological diversity is another important tool for assessing the pollution status of environment. Shannon, Margalef and evenness values were recorded high in station 1, while station 2 and 3 had low values of these indices. The low values in these diversity indices in station 2 and 3 is believed to have emanated from severe stress imposed by anthropogenic activities in the river body at these stations. The high diversity recorded for Shannon and Margalef in station 1 may entail that this station was relatively stable and stress free. However, the high evenness value observed in station 1 may reflect that there was uniformity in the distribution of macro-invertebrates in this station.

5.0 Conclusion

Conclusively, it is believed that the river is impacted with agrochemicals which comes into the river via surface run-off. This stem from the low values of DO and high values of nitrate, phosphate and COD recorded in station 2 and 3 which are closed to agricultural farmlands with extensive use of agrochemicals for pest control and high yield of crops. In terms of macro-invertebrate's abundance and diversity station 2 and 3 had the least when compared to station 1 which was sited far from where there are no farmlands and serves has the control. Based on the findings of this study it is evident that agrochemical have impact on water quality and macro-invertebrate's abundance and distribution in the study area. This study recommends adhering to standard practices in the application of agrochemicals and also, at low concentrations and ridges should be built around farmlands to prevent surface run-off during heavy precipitation.

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5/24/2020