Benthic Macro-Invertebrates as Indicators of Water Quality in Ogunpa River, South-Western Nigeria

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Abstract

This study assessed the water quality of Ogunpa River using benthic macro-invertebrates. Three sampling stations were purposively selected and replicated trice. Benthic samples were collected fortnightly using Van Veen 0.5 m bottom grab for a period of twelve months (January – December, 2018). Water samples were collected from the stations and determined using standard methods. The mean water parameters recorded were; Temperature (26 $^oC \pm 0.12$), Dissolved Oxygen (5.05 mg/L ± 0.47), Chemical Oxygen Demand (29.53 mg/L ± 0.51), Nitrate (4.40 mg/L ± 0.20) and pH (7.82 ± 0.18). Temperature and pH were not significantly different ($P>0.05$), COD and nitrate were significantly different ($P<0.05$) while DO for stations A and B were significantly different ($P<0.05$) from station C. Seven (7) benthic macro-invertebrates namely *Lymnaea truncatula*, *Lymnaea glabra*, *Chironomus sp*., *Gyrius sp*., Anisoptera, *Hirudo sp*. and *Tubifex sp.* belonging to five (5) families were recorded. Overall, a total of 9,989 macro-invertebrates were recorded from all the stations with the highest relative abundance in station C (35.3%). Family Lymnaeidae had the highest abundance (53.1%) while the lowest was Odonata (6.9 %). The abundance of pollution tolerant benthic macro-invertebrate *L. truncatula* (36.5%) indicated that the river is under pollution stress. There is an urgent need for proper management measures to be put in place in order to maintain good water quality for the sustenance of aquatic life and meeting the United Nations Sustainable Development Goal 6 (clean water and sanitation).

Introduction

With the United Nations poised to transform our world by 2030 through the Sustainable Development Goals (SDGs), Goal 6 (clean water and sanitation) is crucial. Water quality is important to human health, well-being, fish production and aquatic life. Water quality is governed by factors that influence species composition, diversity, stability, production and physiological conditions of indigenous populations of both flora and fauna in a water body (Boyd, 1982). Freshwater (which constitutes 2.5 % of the global water) is a scarce commodity due to increased pollutants from either point or non-point sources (Ipinmoroti et al., 2018; Jenyo-Oni and Oladele, 2016; Iyiola, 2015). Pollutants affect the physical, chemical, and microbial quality of water making it unfit for use by fish, livestock, and other organisms (Rodrigues and Cunha, 2017, Dwivedi and Pandey, 2002). The concentration of pollutants varies with time and location. Therefore, physical and chemical monitoring may not detect non-point source pollution problems but the inclusion of biological approach using organisms as the basis for pollution detection is feasible (Adeyemo et al., 2008).

Macro-invertebrates are ubiquitous to aquatic systems and play various roles such as mineralization, mixing of sediments, the flux of oxygen into sediment and cycling of organic matter (George et al., 2009). Macro-invertebrates are also important food sources for animals higher on the food chain. They decay when they die, thereby, releasing nutrients that are reused by aquatic plants and animals in the food chain (Stockley et al., 1998). Their presence is threatened by changes in their habitat associated with pollution, erosion, and siltation (Jenyo-Oni and Oladele, 2016; Lydeard et al., 2004) and can therefore, be used to calculate a water quality index (Adakole and Anunne, 2003). Species vary in their degree of tolerance and the abundance of pollution tolerant species signifies the extent of pollution (Edokpayi et al., 2000). Mayflies (Ephemeroptera), stoneflies (Plecoptera), aquatic snails (Mollusca), beetles (Coleoptera), biting midges (Chironomids), caddisflies (Trichoptera), and leeches (Hirudinea) can be utilized as a measure of aquatic pollution (Tampus et al., 2012).

Water quality indicates the state of the water body although in some cases, it may not depict the actual condition (Balarabe, 2001). To this end, the integration of a biological approach such as the study of macro-invertebrates is essential in order to have a comprehensive picture of the health of a water body (Bonada et al., 2006). The combined approaches of chemical and biological assessment have been widely used in water management. According to Camargo (1993), biological monitoring gives a better picture of pollution indication than water quality alone.

The abundance and distribution of benthic macro-invertebrates changes with prevailing pollution stress and can be used as a biological criterion for assessing the effects of anthropogenic activities on the aquatic system. Biological monitoring is best used in place of chemical monitoring which may be expensive because it requires specific chemicals. Benthic macro-invertebrates are best preferred for monitoring because insects have high diversity, they have limited mobility and ubiquitous to any aquatic environment (Boyle and Fraleigh, 2003).

Ogunpa River is a important river in Ibadan. It flows through a densely populated area with numerous business activities. Studies on water quality management using macro-invertebrates in evaluating the impacts of specific pollutants in aquatic environments have been reported elsewhere (Ugwumba et al., 2011; Esenowo and Ugwumba, 2010; George et al., 2009; Arimoro and Ikomi, 2007; Ogbeibu and Victor, 1989). However, there is a lack of information on the use of benthic macro-invertebrates as an indicator of water quality in the Ogunpa River. The present study seeks to provide baseline information on the health of Ogunpa River using benthic macro-invertebrates as indicators. This will provide information about the water quality and pollution status of the river which will enable necessary management measures by the relevant stakeholders (environmental agency, Defence Intelligence Agency, Bureau Public Enterprises, local government authorities and other organisations).

Materials and Method

Study Area

Ogunpa River is one of the prominent and important rivers in Ibadan metropolis. It flows through the densely populated areas of the city, and in most areas serves as a major dump site for refuse and sewage. It flows through the Bodija market abattoir into the study area located between longitude 3^{o} 56E and latitude 7^{o} 26N (Fig. 1). The river lies within the western part of the country with the wet season which starts in March – October and the dry season which is between November and March (Nigerian Metrological Agency, 2008).

Sampling Stations

Three sampling stations (namely A, B, and C) with three replicates tagged A1, A2, A3, B1,

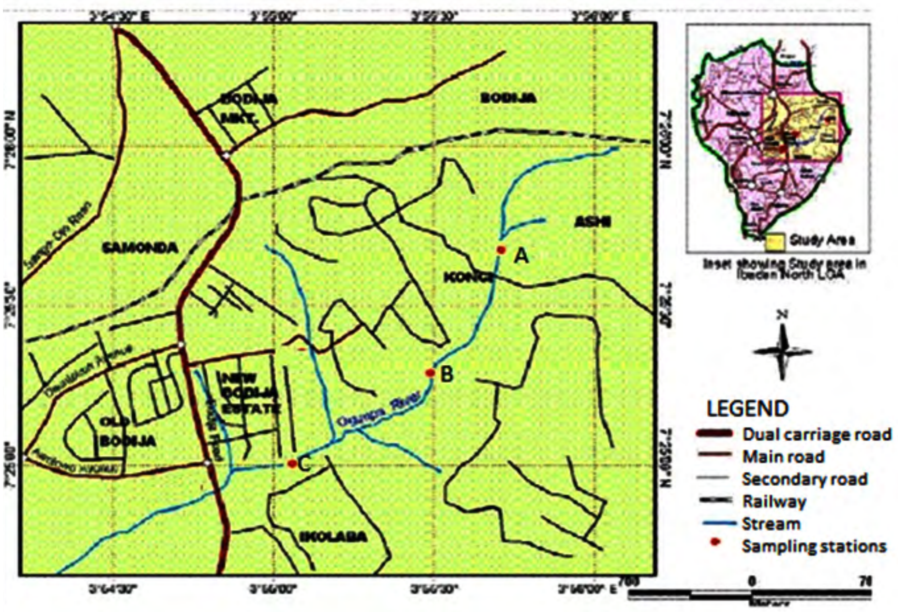

Figure 1: Map of Ogunpa River showing sampling stations

B2, B3, C1, C2 and C3 were selected along the river based on accessibility and characteristics of the area.

Station A: This station was located close to the source of the river (Fig. 1). The station was dominated by human activities such as horticulture, mechanic activities, and residential buildings all of which emptied their wastes into the River. The flow rate of water was slow, and the water was turbid due to clay from construction and expansion of the river course.

Station B: This station was located about 200 meters away from station A (Fig. 1). This station was composed of residential buildings but not as populated as station A. Human activities and the flow of water in this area was similar to that in station A. The water was dark in colour and loaded with a lot of refuse dumped in the river and sewage discharge.

Station C: This station was located about 200 meters from station B (Fig. 1). It had few residential buildings compared to stations A and B. The station was mainly surronded by aquatic vegetation and was void of refuse dumps. The colour of the water was clear; the water depth was shallow to a point where the substratum was visible and fast flowing.

Measurement of Water Quality Parameters

Water samples were collected fortnightly for twelve months (January – December, 2018). from the sampling stations between the hours of 7.00 am and 7.30 am (GMT -1). The reference for the water quality parameters was based on WHO (2001). Parameters measured were dissolved oxygen (DO) concentration, temperature, nitrate, pH, and chemical oxygen demand (COD).

DO, nitrate and pH were measured using API Freshwater Master Test Kit (MARS Fishcare, 2016). The procedure for testing was followed as described in the instruction manual by the manufacturer. Values were determined by comparing the colour of the test solution with the colour charts provided.

Temperature was measured using a mercury-in-glass thermometer. It was immersed in-situ in the sampling stations to a depth of 10 mm for 2 minutes (based on Atobatele et al., 2005). COD was determined using the dichromate reflux method as stated by the American Public Health Association (2012). The formula used

$$COD\ (mg/L) = \frac{(a - b)(N)x\ 8{,}000}{sample\ size\ (ml)}$$

was:

Where:

a = ml $Fe(NH_4)_2(SO_4)_2$ used for blank

b = ml $Fe(NH_4)_2(SO_4)_2$ used for sample

N = normality of FAS titrant ($Fe(NH4)_2(SO4)_2$)

ml sample = the actual volume of sample used before dilution

Collection of Benthic Macro-Invertebrate Samples

Fortnight sampling of benthic macro-invertebrates was carried out for twelve months (January – December, 2018). Van Veen grab of 0.5 m^2 was used to collect benthic sediment samples from each sampling station. Macro-invertebrate samples were preserved in 4 % formalin as described by Barbou (1999) and transported in labelled polythene bags to the laboratory for identification with the aid of hand lens and dissecting microscope. In the laboratory, each sediment sample was diluted with water, washed three times, and sieved with three types of sieve mesh sizes (2 mm, 1 mm, and 0.5 mm). The residuals on the screens of the sieves were washed into a shallow white tray with water for sorting using Binocular microscope (American Optical Corporation model 570). Large ones were picked with a pair of forceps and the smaller ones were picked with the aid of pipette from the samples. The sorted macro-invertebrate organisms were preserved in 4 % formalin in labelled small glass containers (Barbou, 1999). Individual organisms were identified with Olympus Vanox Research Microscope Model 230485 (Mag. 50-500x) using a combination of guides (Pennak, 1978; Ogbeibu and Victor, 1989; River Watch Network, 1992).

Biological Diversity of Macro-Invertebrates

The species composition and abundance in the river was determined using Shannon-Wiener index (H) and Evenness (E) as described by

$$Shannon\ weiner\ (H) = \frac{NlogN - nlogn}{N}$$

Shannon and Wiener (1949) as follows:

Where:

N = Total number of individuals present in all the sampling stations

n = Total number of individuals in each sampling station

$$Evenness\ (E) = \frac{H}{Hmax}$$

Where:

H = Shannon Wiener diversity index

H_{max} = Natural log of richness

Margalef's index (d) takes cognizance of the richness and species diversity of benthic macro-invertebrates in the community structure. It was determined using Margalef (1967) as follows:

$$d = \frac{S - 1}{\ln(N)}$$

Where:

d = Species richness index

S = Number of species population

N = total number of individual species

Statistical Analysis

Water quality parameters were analyzed using one-way Analysis of Variance (ANOVA) at P<0.05 level of significance.

Results

Water Quality Parameters

The results of the water quality parameters measured from the river are presented in Table 1. The mean water temperature was 26.01°C ± 0.12 while pH was 7.82 ± 0.12. The mean DO, COD and nitrate were 5.05mg/L±0.47, 29.53mg/L±0.51, 4.40mg/L±0.20, respectively. Temperature, pH and DO were not significantly different (P>0.05) among the stations. However, COD and nitrate were significantly different (P<0.05) among the three sampling stations.

Composition of Benthic Macro-Invertebrates and Abundance

The relative abundance of benthic macro-invertebrates counted from the sampling stations is presented in Table 2. A total of 9,989 individuals belonging to 5 taxa and 7 species were recorded. Family Lymnaeidae had the highest relative abundance (53.1 %) while the lowest was family Odonata (6.9 %). In terms of sampling stations, station C had the highest total relative abundance (35.3 %) while the lowest was station A (31.1 %). Family Chironomidae had only one species namely *Chironomus sp*, and the highest abundance was in station B (536) while the lowest was in station C (306). Family Gyrinidae had only one species namely *Gyrius sp.*, and the highest abundance was in station A (336) and the lowest was in station B (96). For family Lymnaeidae which had two species, *Lymnaea truncatula* was highest in station B (1485) and lowest in station C (896) while for *L. glabra* was highest in station A (624) and lowest in station C (454). For family Odonata which had two species, *Anisoptera* was highest in station

TABLE 1

Mean values of water quality parameters measured from the three stations during the study

Parameters	Station A (Mean)	Station B (Mean)	Station C (Mean)	Overall mean	WHO (2001)
Temperature (°C)	26.15 ± 0.12 ^{a}	25.99 ± 0.12 ^{a}	25.90 ±0.13 ^{a}	26.01± 0.12	21 – 30
pH	7.73 ± 0.21 ^{a}	7.89 ± 0.13 ^{a}	7.86 ± 0.20 a	7.82 ± 0.18	6.6 – 8.5
DO (mg/L)	3.13 ± 0.15 ^{a}	4.89 ± 1.10 ^{a}	7.15 ± 0.17^{b}	5.05 ± 0.47	5 - 8
COD (mg/L)	36.10 ± 0.85 c	34.20 ± 0.49^{b}	18.30 ±0.19^{a}	29.53 ± 0.51	20 - 30
Nitrate (mg/L)	5.31 ± 0.13 ^{b}	7.12 ± 0.24 ^{c}	0.78 ± 0.25 ^{a}	4.40 ± 0.20	1.00

Rows with different similar superscripts are significant (P<0.05)

TABLE 2

Relative abundance of benthic macro-invertebrates counted from sampling stations

Family	Species	Station A	Station B	Station C	Total	Relative abundance
Chironomidae	*Chironomus sp*	512	536	306	1354	13.6
Gyrinidae	*Gyrius sp.*	336	96	276	708	7.1
Lymnaeidae	*Lymnaea truncatula*	1264	1485	896	3645	36.5
	L. glabra	624	576	454	1654	16.6
Odonata	*Anisoptera*	124	160	70	354	3.5
	Hurudo sp.	119	90	128	337	3.4
Tubificidae	*Tubifex sp.*	128	408	1401	1937	19.4
	Total sample	3107	3351	3531	9989	100
	Relative abundance (%)	31.1	33.5	35.3	100	100

B (160) and lowest in station C (70) while *Hurudo sp*. was highest in station C (128) and lowest in station B (90). Family Tubificidae had only *Tubifex sp*. with highest in station C (1401) and lowest in station A (128).

Biological Diversity of Macro-Invertebrates

The diversity indices calculated are presented in Table 3. The stations had the same number of taxa and species richness. The number of individuals was highest in station C, followed by station B and lowest in station A. Shannon-Wiener was highest in station A (2.91) and lowest in station C (2.75). Evenness was highest in station A (3.45) and lowest in station C (3.25). Margalef's index was highest in station A (1.71) and lowest in station C (1.69).

TABLE 3
Diversity indices of benthic macro-invertebrates

Indices	Site A	Site B	Site C
Number of Taxa	5	5	5
Richness (R)	7	7	7
Number of Individuals (N)	3107	3351	3531
Shannon-Wiener index (H)	2.91	2.81	2.75
Evenness (E)	3.45	3.33	3.25
Margalef's Index (d)	1.71	1.70	1.69

Discussion

Water Quality Parameters

Water quality is important for species abundance and biological properties in an aquatic system (Ibrahim and Nafi'u, 2017) as well as the food chain. It can be affected by the prevailing environmental conditions due to human activities (Iyiola, 2015; Idowu and Ugwumba, 2005). In fisheries and aquaculture, poor water quality reduces growth which ultimately affect fishers' profit. The mean water quality parameters recorded from the river varied across the sampling stations and were within the recommended levels for aquatic life WHO (2001) except for nitrate. The high nitrate level may be due to activities such as horticulture and refuse dumps /sewage into the river. Ugwumba et al. (2011) also reported a high nitrate level in the Ogunpa river. The mean temperature recorded was within the recommended range of 21-30 ^{o}C (Boyd and Linchtkoppler, 1979). Kolawole and Iyiola (2018) and Komolafe et al. (2014) reported similar results on temperature variations in some rivers within the region. The overall mean DO recorded (5.05 mg/L ± 0.47) was within the recommended range of 5-8 mg/L (WHO, 2001). The higher DO level in station C (7.15 mg/L ± 0.17) was due to the aeration and photosynthetic activities by aquatic plants which are peculiar in the area and the fast flow of water which constantly replenishes the oxygen content in water (Jaji et al., 2007; Ayoade, 2004). The DO concentration in station A (3.13mg/L ± 0.15) was low and possibly due to the decomposition of various organic and inorganic materials which was prevalent in the sampling station which inhibited oxygen concentration in the water (Idowu and Ugwumba, 2005). The overall mean pH recorded (7.82 ± 0.18) was within the recommended range of 6.6 – 8.5 as stated by Boyd and Linchtkoppler (1979). In the present study, the mean COD recorded in stations A (36.10 mg/L ± 0.85) and B (34.20 mg/L ± 0.49) were above the recommended levels of 20-30 (WHO, 2001). These were expected because of the peculiarity of wastes generated from mechanic activities in these stations (Umar and Bashir, 2014; Idowu and Ugwumba, 2005).

Abundance and Composition of Benthic Bacro-Invertebrates

The abundance of macro-invertebrates in a waterbody is related to the water condition, availability of food, and the quality of substrate of the water body (Suleiman and Abdullahi, 2011). Ogunpa River flows through the Bodija market abattoir and is open to human activities which can affect the aquatic system. The family Lymnaeidae was observed to be dominant (53.1 %) in the river during the period. The presence of *Lymnaea sp*. and *Chironomus sp*. are indicator species of organic pollution in rivers which receives domestic and industrial sewage (Ugwumba et al. 2011). Ibrahin and Nafi'u (2017), Sharma et al. (2007), and Ibrahim (2009) reported similar cases of these species as indicators of pollution in water. *Chironomus sp*. can easily adapt and tolerate polluted waters because of the presence of the pigment hemoglobin which has a high affinity for oxygen (Mason, 1991). These pollution tolerant species were abundant in stations A (*L. truncatula*: 1,264; *L. glabra*: 624 and *Chironomus sp*.: 512) and B (*L. truncatula*: 1,485; *L. glabra*: 576 and *Chironomus sp*: 538) which was favoured by the increased COD (36.10 mg/L ± 0.85 and 34.20 mg/L ± 0.49 for stations A and B, respectively) and nitrate levels (5.31mg/L ± 0.13 and 7.12mg/L ± 0.24) of the water caused by the prevailing human activities in these areas. Station C had the lowest abundance of pollution tolerant species (*L. truncatula*: 896; *L. glabra*: 454 and *Chironomus sp*.: 306) when compared with other stations. This was due to the good quality of water when compared with the other stations; DO was highest (7.15 mg/L ± 0.17), nitrate was less than the optimum level of 1 (0.78 mg/L ± 0.25) and COD was less than the optimum level of 20-30 (18.30 mg/L ±0.19) as recommended by WHO (2001). *Tubifex sp*. which is a pollution intolerant species was the most abundant in station C (1,401) and its presence is an indication of good water quality in that station (Ibrahin and Nafi'u, 2017). The dominance of pollution tolerant benthic macro-invertebrates in Ogunpa River during the studied period is a clear indication of a high rate of organic pollution. Yap et al. (2013) reported similar results which were attributed to pollution stress having a direct impact on the abundance and diversity of macro-invertebrate species in the river.

Biological Diversity of Benthic Macro-Invertebrates

Shannon-Wiener (H) indices provide information about the species composition and representativeness in an aquatic system. The H value decreased progressively from station A (2.91) to station C (2.75). These values fell within the range of 1.5 and 3.5 which are for real communities (Shannon and Wiener, 1949). Station A was more diverse in benthic macro-invertebrate composition because it has the highest H value. This implies that when benthic macro-invertebrate species are selected, they are all represented in the sample. Uguumba et al. (2011) and Tyokumbur et al. (2002) reported a similar occurrence of macro-invertebrate composition in Ogunpa and Awba stream in Nigeria.

Margalef's index (d) takes cognizance of the richness and species diversity of benthic macro-invertebrates in the community structure (Margalef, 1967). It decreased from station A (1.71) to C (1.69) which implied that station A was richer and more diverse than stations B and C.

Conclusion

It was observed that Ogunpa River is polluted as indicated by the abundance of pollution tolerant benthic macro-invertebrate indicator species. Their abundance is not favourable and is a clear indication of poor water quality which resulted from the stress imposed by land-based pollutants such as refuse and sewage into rivers and discharges within the study area. The source of pollution must be controlled as well as regular monitoring of the water quality. There is a need for strict adherence to clean environmental measures for the sustenance of aquatic life and a healthy river system in realizing sustainable development goals 6: clean water and sanitation.

Acknowledgments

We thank the anonymous reviewers for reading and making insightful comments.

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