LEAD (Pb) ACCUMULATION IN WATER, SEDIMENT AND DISTRIBUTION OF MACRO-INVERTEBRATES IN DELIMI RIVER, JOS, NIGERIA

ABSTRACT

Background: This study assessed the concentrations of lead (Pb) in the water column and sediment as well as macro-invertebrates in River Delimi with a view to determining its ability to support aquatic life.

Methodology: Water samples were collected between August and November 2019 from specified locations identified as stations A (Abattoir), B (British America bridge), and C (Farin Gada bridge). These samples were taken at a depth of 30cm using 250 ml plastic bottles that were cleaned with detergent and distilled water before use. A total of 36 sediment samples were collected from stations A, B, and C during the same period. These sediment samples, weighing 500g each, were placed in airtight polythene bags, sun-dried for three days, and then homogenized by grinding. Macroinvertebrates were collected using a D-frame kick-net (30) at each site over a three-minute period. The collected specimens were preserved in 70% formalin and transported to the laboratory for sorting, identification, and enumeration.

Result: Showed that the concentration of lead (Pb) in all the water samples were found to be less than the permissible limit set by WHO/FAO except site WA3 (0.0874ppm) and WC3 (0.0678 ppm) which were higher than permissible limit. The concentration of lead (Pb) in sediment was higher than the WHO/FAO permissible limit in all sampling stations which is most likely to pose serious health risks to macrobenthos. Also, 7 Micro-invertebrate taxa were identified in the sampling stations. Chironomidae, Eristalis Larva (Syrphidae), Tabanidae and Whirligig beetle (Gyrinidae) comprised more than 79% of the total abundance while stone fly Larva, hydrophilidae and beetle larva constituted the remaining.

Conclusion: water samples suggests potential environmental contamination of lead in some locations while sediment samples indicates a significant contamination with lead, posing potential health risks to organisms living in the sediment, including macrobenthos.

1. INTRODUCTION

In the last two decades, Nigeria's modern cities have experienced an increase in industrial boom, urban migration and also increased human and vehicular activities [1]. These activities increase environmental pollution through the release of toxic substances into the atmosphere and have resulted in sundry contaminants in agricultural soils [1]. The pollution of soil, atmosphere and water bodies by toxic metals can be persistent and irreversible [2]. These discharges have caused serious ecological alteration of water resources in Nigeria [3]. Most rivers in Nigeria, particularly those in urban and semi urban cities are now being used for discarding both solid and liquid wastes. These high-polluting activities are now threatening the sustainability and functionality of freshwater ecosystems in Nigeria (4,5]. Industrial and anthropogenic activities, fishing, quarrying, sprawling urbanization, and water pollution are common issues among rivers that have threatened the quality of fresh water [6,7]. Urbanization and industrialization are implicated as major stressors causing the degradation of riverine systems [8]. Urbanization and industrialization result in storm water return flow, sewage disposition, agricultural runoffs, and effluent discharges. This problem causes water quality impairment and biodiversity decline of freshwater ecosystems, causing serious management issues for water quality managers and policymakers [9]. If not tackled urgently, it could have a grave effect on the riverine system's community structure and functionality [10]. The presence of certain metals such as lead (Pb), cadmium (Cd) and mercury (Hg) in the environment is of public health concern when their concentrations are higher than permissible concentration set by WHO/FAO, USEPA and EU in different matrices [11,12]. Exposure to lead (Pb) occurs mainly via inhalation and ingestion from contaminated foods, which may pose threat to human health especially children who may suffer a high health risk (elevated Blood Lead Level) due to the bio accumulative potential [13,14]. Natural and anthropogenic activities in urban cities which include mining, smelting, industrial emission, waste incineration, coal burning and vehicle exhaust emission are sources of lead (Pb) pollution in the environment [15,16]. Exposure to Lead among populations living in developing countries occur primarily due to economic and social vulnerability when they engage in informal activities (waste recycling and crude mining) that release Lead (Pb) into the environment [17]. Unlike in developed countries, the majority of the populations in Nigeria are unaware of the toxic effects of Lead (Pb) exposure hence the population is at high risk. It has been established that most of the solid waste generated in the city is dumped in the rivers [18]. River Delimi and Jenta are the major source of water for irrigation in and around the Jos city [19]. These rivers contain a substantial amount of beneficial nutrients and toxic heavy metals, which creates opportunities and problems for agricultural production. The aquatic environment is heavily degraded due to various anthropogenic activities that cause domestic and industrial effluents particularly rivers, lakes, and the reservoirs (aquatic ecosystem) located near industrial and urban areas are the potential target for the disposal of the environmentally harmful elements like organic and inorganic contaminants [20]. Thus, a comprehensive health risk assessment of agricultural soils in this region is urgently needed, to assess the level of soil pollution by Lead (Pb) due to mining activities.

Heavy metals are of particular concern due to their non-biodegradable nature and their detrimental effect to human health. These heavy metals have a high ability to bio-accumulate in various organs and muscle tissue of fish [21]. In the aquatic environment trace elements are distributed between dissolved phase, colloids, suspended matter and sedimentary phases. In the hydrological cycle, less than 0.1% of the metals are actually dissolved in the water and more than 99.9% are stored in sediments and soils [22]. Human activities such as mining, manufacturing and fossil fuel burning has resulted in the accumulation of Lead and its compounds in the environment, including air, water and soil [23]. Lead is used for the production of batteries, cosmetics, metal products such as ammunitions, solder and pipes among others [24]. Lead is highly toxic and hence its use in various products, such as paints, gasoline among others has been considerably reduced nowadays. The main sources of Lead exposure are Lead (Pb) based paints, gasoline, cosmetics, toys, household dust, contaminated soil, industrial emissions [25]. Acute exposure mainly occurs in the place of work and in some manufacturing industries which make use of lead [23]. Chronic exposure of lead can result in mental retardation, birth defects, psychosis, autism, allergies, dyslexia, weight loss, hyperactivity, muscular weakness, brain damage, kidney damage and may even cause death [23]. Lead (Pb) is a pervasive environmental contaminant and the adverse health effects of lead (Pb) exposure in children and adults are well documented but no safe blood lead threshold in children has been identified [26]. The spatiotemporal functional and structural compositions of macroinvertebrate assemblage in any stream system can be influenced by human activities [27]. Benthic macroinvertebrate assemblages contain species with various sensitivities to contaminants and have been widely used to evaluate the ecological impacts of metal contamination in streams [28]. Metal contamination can reduce benthic macro invertebrate species richness, as well as density, growth and production [29]. The effects of heavy metals on macro-invertebrates are highly variable among taxa and may also have an effect on ecosystem function. [30] recorded a change in functional feeding groups (FFG) of benthic macro invertebrates with lower abundances of scrapers, shredders, collectors, and predators at stations with medium and high-concentrations of heavy metals, compared with reference stations. Benthic macro-invertebrates however, were found to be more sensitive to heavy metals at higher elevations [30].

2. MATERIALS AND METHODS

2.1 **Study area**

This study was conducted at River Delimi of Jos-North local government area, Plateau State. Water from this River is used for domestic purposes and irrigation. Jos North local government area is located at the extreme north of Plateau State on latitude 09^0 53' and 09^0 059' North, and Longitude 08^0 51' and 09^0 02' East. It shares boundary to the North with Toro local government area of Bauchi State; to the South with Jos South local government area; to the North-East with Jos- East local government area, and to the West with Bassa local government area. Jos North local government area enjoys a temperate climate with average temperature of between 11 ^{0}C minimum and 28 ^{0}C maximum. It covers the total land area of $291km^2$. Jos-North local government area is characterized by a mean annual rainfall of between 1317.5mm (131.75cm) and 1460.00mm (146cm), mostly in May to August.

2.2 Collection and Preparation of Samples

Water Samples were collected from August to November 2019 from predetermined sampling points which were designated station A (Abattoir), B (British America bridge) and C (Farin Gada bridge). The water samples were collected in 250 ml capacity plastic bottles with screw caps at 30cm depth. The plastic bottles had previously washed with detergent and finally rinsed using distilled water. Physicochemical parameters of the water were monitored for each sampling station using the methods described by [31].

A total of thirty-six (36) sediment samples were collected from station A, B and C from August to November. The sampling distance from one station to another was at least 2km. The sample mass collected were in airtight polythene bags measuring 500g each. Sub-samples of the material were sun-dried for three (3) days and homogenized by grinding in laboratory mortar and pestle and sieved (aperture 125 µm) then stored in glass bottles for chemical analyses.

Macroinvertebrates were collected using a D-frame kick-net (30) at each site for three minutes. The samples collected were preserved in 70% formalin and taken to the laboratory for sorting, identification and enumeration following [32,33,34,35]. Macroinvertebrates were identified to family level using light microscope at x10 magnification and other available keys.

2.3 Determination of Lead(pb) Concentration in Samples

Total concentrations of lead (Pb) in water and sediment samples were determined using an atomic absorption spectrophotometer (Varian Spectr AA 20), equipped with single elements hollow-cathode lamps at the wavelengths of 324.7, 213.9, 283.3, 228.8, 232.0 and 357.9 nm, respectively. For the determination of total heavy metal concentration in sediment, exactly 1.00g of powdered sediment sample was digested with aqua regia (HNO_3 HCl = 1: 3). Before use, all glass and plastic wares were soaked in 14% HNO_3 for 24 hrs. The washing was completed with a distilled water rinse.

2.4 Data Analyses

Statistical analysis was done on SPSS using the one-way ANOVA to determine if there is any significant difference between the means of the samples collected from the three locations. Values were considered statistically significant at P=.05.

3. RESULTS AND DISCUSSION

3.1 Water Quality Parameters

The water quality characteristics revealed that temperature ranged between 22.00-23.00℃ with the value of station C higher than station A and B, pH ranged 5.40-7.90g/L with station C having lowest value than station A and B. The low pH (below 7) in water collected at station B and C indicated that it is slightly acidic. Dissolved oxygen ranged from 4.20-11.20mg/L indicating higher dissolved oxygen in station A and B than station C, free carbon dioxide ranged from 90.00-120.00mg/L with station C having higher value than station A and B while alkalinity ranged 50.00-136.00mg/L with station A having lower value (50.00 mg/L) than station B (66.00 mg/L) and C (136.00 mg/L) respectively. Earlier studies by Absalom *et al* (2005) recorded similar values while studying the Coliform, Planktonic and Macro-invertebrates of river Delimi.

Table 1 Mean water quality parameters monitored during the experimental period

Parameter	Station A	Station B	Station C
Temperature (°C)	22.50±0.1	22.00 ±0.3	23.00±0.1
Ph	7.90±0.2	6.50±0.1	5.40 ±0.1
Dissolved oxygen (mg/L)	11.20±0.1	9.50 ±0.2	4.20±0.1
Free carbon dioxide (mg/L)	90.00±0.2	100.00±0.2	120.80±0.4
Alkalinity(mg/L)	50.00 ±0.1	66.00±0.3	136.00±0.5

3.2 Concentration Of Lead (Pb) In Water Column

Anthropogenic activities like mining, farming and indiscriminate refuse dumping alter the clean water and soil composition and are considered one of the most significant sources of Lead(Pb) pollution in rivers (Acosta et al., 2011; Zhuang et al., 2009). The local residents living around Abattoir, British America and Farin Gada communities mainly engage in farming and artisanal mining as part of their occupation. The three (3) communities showed diverse concentration of lead (Pb) in water of river Delimi. as shown in Table 2, the mean lead concentrations in water collected from the three Sites ranged from 0.0085 – 0.0874 ppm with highest concentrations in WA3 (Abattoir) and WC3 (Farin Gada) with values higher than the permissible limit of 0.01 ppm provided by WHO/FAO which is in agreement with [18]. Concentrations were lower in WA1 (Abattoir) as well as WB1 (British America).

Table 2: Concentration (ppm) of Lead (pb)in water column of River Delimi

Sampling Period	Sampling Stations								
	Station A			Station B			Station C		
	WA1	**WA2**	**WA3**	**WB1**	**WB2**	**WB3**	**WC1**	**WC2**	**WC3**
August	0.0455	0.0315	0.0874	0.0105	0.0245	0.0315	0.0245	0.0245	0.0455
September	0.0085	0.0339	0.0424	0.0169	0.0339	0.0085	0.0508	0.0085	0.0678
October	0.0433	0.0234	0.0385	0.0265	0.0532	0.0428	0.0365	0.0423	0.0371
November	0.0588	0.0588	0.0392	0.0000	0.0339	0.0294	0.0392	0.0490	0.0392

3.3 Concentration of Lead(Pb) In Sediment

A study carried out by [36] suggested that dumping of different waste materials such as plastics, electrical and electronic materials, metal scraps, old batteries, spent lubricating oil from nearby mechanic workshops along the Delimi River bank may be responsible for the high level of heavy metals in the river water. Although sediment have heavy metal immobilizing capability, the ability of metals to bio-accumulate over a period of time will result in uptake by benthic organisms in the contaminated soils. Since Lead (Pb) is not very mobile in soil, concentrations of lead in soil which are representative of the degree of pollution/contamination may not directly be linked to an adverse health effect without conducting a health risk assessment of the organisms, because only a fraction is taken up by the organisms [37]. The bioavailable metal content in water and soil exerts a significant impact on water quality and this might affect food safety and biodiversity of macro invertebrates. Hence, the assessment of heavy metal contamination is of public health importance in agricultural soils [38]. The disparity in concentration observed in this studies could be as a result of the different contamination source. The increase in Blood Lead Level (BLL) among Nigerians may not be unconnected to environmental Lead (Pb) emission from industries, mines and leaded gasoline due to limited regulatory restrictions from the relevant government agencies to check pollution. Lead (Pb) accumulates in sediment and can pose a hazard to sediment dwelling organisms at concentration above 30.2ppm according to Canadian interim marine sediment quality guideline [39].

Table 3: Concentration (ppm) of Lead (pb) in Sediment of River Delimi in Four (4) months

Sampling Period	Sampling Stations								
	Station A			Station B			Station C		
	A1	**A2**	**A3**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**
August	25.85	19.07	7.63	12.29	15.25	17.37	31.36	29.66	34.32
September	91.53	43.22	60.17	32.20	40.68	54.24	38.14	39.83	123.20
October	128.32	201.77	240.26	84.07	125.66	80.53	58.41	570.80	120.35
November	43.14	47.06	143.14	33.33	49.02	154.90	418.63	665.69	88.24

3.4 Macro-invertebrates Distribution

A total of 7 macro-invertebrates taxa were identified in the three (3) sampling stations of River Delimi. Chironomidae, *Eristalis* Larva (Syrphidae), Tabanidae and Whirligig beetle (*Gyrinidae*) comprised more than 79% of the total abundance, while stonefly Larva, Hydrophilid beetle and beetle larva (*Coleoptera*) constitute 21% of the total abundance, respectively. As seen in table 4, it will be observed that only two (2) taxa (hydrophilid beetle and whirling beetle) were found in station A implying moderate water quality of the station. While the presence of *Eristalis* larva and *Chironomus* larva though in low index suggest that station B is slightly polluted. The high dominance index of *Chironomus* larva and *Eristalis* larva indicates that station C were unstable using imbalance of ecosystem. Usually certain organism like *Chironomus* sp. can thrive in an environment with high organic contamination. Most Chironomidae larvae are efficient indicators of mesotrophic waters, and these are usually found at location having high decomposed organic matter. Thus, presence of the Chironomidae family by higher percentage reflected that station C was highly polluted. According to [40,41], *Chironomus* species are indicator of waters contaminated by high load of organic waste. According to [42], Studying macro-invertebrate diversity is one of the most effective and inexpensive ways to estimate the ecological quality of the waters. For example, measurements of the physical and chemical properties of water can also be used to estimate its quality but such measurements cannot exactly represent its actual state. Therefore, it is necessary to combine physical, chemical, and biological evaluation along with other monitoring methods to provide a comprehensive picture of environmental water quality [43]. Biological monitoring using macro-invertebrates has been found accurate and advantageous compared with using other organisms because macro-invertebrates are extremely sensitive to organic pollutants, widely distributed, and easy and economical to sample [42].

Table 4: Species composition, abundance and distribution of Macro-invertebrates in River Delimi.

Order	Family	Taxa	Stations			Pollution Status
			A	B	C	
Coleoptera	Dysticidae	*Phylodyte Sp*	0	0	10	Very tolerant
	Hydrophilidae	*Crenis Sp*	5	6	0	Sensitive
	Tabanidae	*Tabanus Sp*	0	0	4	Tolerant
Diptera	Chironomidae	*Chironomus Sp*	0	2	18	Very tolerant
	Syrphidae	*Unknown Sp*	0	4	14	Very tolerant
Ephemeroptera	Gyrinidae	*Orectochilus Sp*	4	6	0	Sensitive
Plecoptera	Unidentified	Unidentified	0	0	12	Very tolerant

4. Conclusion

In conclusion, Delimi River received certain pollutants and can be categorized as a polluted river. [14], described numerous sources of Lead (Pb) as sewage sludge, leaded gasoline from vehicular traffic and industrial emission, but recent studies have shown that mining could be a major source point of Lead (Pb) pollution in agricultural soils. The high level of Lead in sediment suggests that sediment dwelling organisms are likely to bio accumulate Lead over time. This study also provides insights on the impacts of environmental variables on the diversity of macro-invertebrate assemblage in River Delimi. Given the negative effects of Lead (Pb) consumption on human lives and macro-invertebrates, the study recommended that: government should enforce the ever-existing law that bans dumping of refuse, sewage and industrial waste into rivers. Restriction of human, industrial and agricultural discharges to this River is required with continuous monitoring to ensure that the concentrations of Lead remain within the prescribed worldwide limits to protect it from further deterioration.

REFERENCE

[1] Orisakwe, O.E. (2017). Lead level in vegetables from Artisanal mining sites of Dilimi River, Bukuru and Barking Ladi North Central Nigeria. *Asian Pacific Journal of Cancer Prevention. 18(3):621-627*

[2] Wang, Q.R., Dong, Y., Cui, Y. & Liu, X. (2001). Instances of soil and crop heavy metal contamination in China. *Soil Sediment Contamination, 10,497–510.*

[3] Arimoro, F. O. & Ikomi, R. B. (2008). Response of macroinvertebrates to abattoir wastes and other anthropogenic activities in a municipal stream in the Niger Delta.

[4] Arimoro, F. O. (2009). Impact of rubber effluent discharges on the water quality and macroinvertebrate community assemblages in a forest stream in the Niger Delta, Nigeria. Chemosphere, 77, 440–449.

[5] Arimoro, F. O. & Oganah, A. O. (2010). Response of zooplankton to abattoir wastes and other anthropogenic activities in a stream in the Niger Delta. The Open Environmental & Biological Monitoring, 3, 1–11.

[6] Arimoro, F.O., Auta, Y.I., Odume, O.N., Keke, N.U. & Mohammed, A.Z. (2018a). Mouthpart deformities in Chironomidae (Diptera) as bioindicators of heavy metals pollution in Shiroro Lake, Niger State, Nigeria. Ecotoxicology Environmental Safety 149:96-100.ATSDR (2010). Agency for toxic substance and disease registry, public health assessment and health consultation. CENEX supply and marketing, Incorporated, Quicy, Grant County, Washington. Beijing, China. *Environmental Pollution. 15,86–92.*

[7] Keke, U.N., Arimoro, F.O., Avanwale, A.V., Odume, O.N. & Edegbene, A.O. (2020b). biodiversity patterns along seasonality and environmental factors of stream macroinvertebrate communities of North-Central Nigeria. Egyptian Journal of Aquatic Biology Fish 24(4):521-534.

[8] Keke, U.N., Omoigberale, M.O., Ezenwa, I., Yusuf, A., Biose, E. & Nweke, N. (2021). Macroinvertebrate communities and physicochemical characteristics along an anthropogenic stress gradient in a southern Nigerian stream: Implication for ecological restoration. Environmental Sustainability Indication. 12: 100157. DOI:10.1016/j.indic.2021.100157.

[9] Blessing, O.O., Arimoro, F.O., Anvanwale, A.V., Egwim, E.c., Omovoh, G.O., Akamagwuna, F.C., Zakari, H. & Edegbene, A.O. (2022). Macroinvertebrates of Wupa River, Abuja, Nigeria: Do environmental variables pattern their assemblages?

[10] Luo, X.S., Yu, S., Zhu, Y.G. & Li, X.D. (2012). Trace metal contamination in urban soils of China. Science Total Environt, 421,17–30.

[11] Fakhri, Y., Mohseni, S.M. & Jafarzadeh, S. (2015). Assessment of carcinogenic and non carcinogenic risk lead in bottled water in different age groups in Bandar Abbas Ciry, Iran. *Global Journal Health Science, 7,286.*

[12] Ahmad, A., Mushrifah, I. & Othman, M.S. (2009). Water quality and heavy metal concentrations in sediment of Sunagi Kelantan, Kelantan, Malaysia, ***A** journal of baseline study* 38,435–442.

[13] Paul, A.W., Kevin, A.H., Waren, D.A. & Sebnem, E. (2013). Assessment and Transport of Sediment- Bound Estuarine Contaminants. *Doi:10.1007/s12403-013-0101-7.*
[14] Hu, X., Sun, Y. & Ding, Z. (2014). Lead contamination and transfer in urban environmental compartments analyzed by lead levels and isotopic compositions. *Environmental Pollution, 187:42-48.*
[15] Charlesworth, S., De Miguel E. & Ordonez, A. (2011). A review of the distribution of particulate trace elements in urban terrestrial environments and its application to considerations of risk. *Environmental Geochemical Health,* 33,103–123.
[16] Wei, B.G. & Yang, L.S. (2010). A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. *Microchemical Journal, 94,99-107.*
[17] Pascale, A., Sosa, A. & Bares, C. (2013). E-Waste informal recycling: An emerging source of Lead exposure in south-America. *Annual Global Health, 82,197-201.*
[18] Farooq, M. & Umar R (2008). Appraisal of heavy metal in different vegetables grown in the vicinity of an industrial area Pak. *Journal of Botany, 40(5),2099-2106.*
[19] Abdullahi, M.S., Uzairu, A. & Okunota, O.J. (2009). Quantitative determination of heavy metal concentrations in onion leaves. *International Journal of Environs Resources, 3,271-274.*
[20] Kamaludeen, S.P.B.K., Arunkumar, K.R., Avudainayagam, S., &Ramasamy, K. (2003). Bioremediation of chromium contaminated environments. *Indian Journal of Experimental Biology, 41, 972-985.*
[21] DeForest, D. K., Brix, K. V. & Adams, W. J. (2007). Assessing metal bioaccumulation in aquatic environments: The inverse relationship between bioaccumulation factors, trophic transfer factors and exposure concentration.*Aquatic Toxicology, 84(2), 236–246.*
[22] Pradit, S., Wattayakorn, G., Angsupanich, S., Leemaker, M. & Baeyens, W. (2010). Distribution of trace elements in sediments and biota of Songkhla Lake, southern Thailand. *Water Air Soil Pollution, 206,155- 174.*
[23] Jaishankar, M. (2014). Toxicity mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology. 7(2):60-72*
[24] Martin, S. & Griswold W. (2009). Human health effects of heavy metals. *Environmental Science and Tecnology Briefs for Citizens, 6(4),79-82.*
[25] Gerhardsson, L., Dahlin, L., Knebel, R. & Schutz, A. (2002). Blood lead concentration after a shotgun accident. *Environmental Health Perspective,* 110(1),115–117.
[26] Brown, M.J. & Margoli, S. (2012). Lead in Drinking Water and Human Blood Lead Levels in the United States vol.61, Aug 10.
[27] Arimoro, F. O., Obi-Iyeke, G. & Obukeni, P. J. O. (2012). Spatiotemporal variation of macroinvertebrates in relation to canopy cover and other environmental factors in Eriora River, Niger Delta, Nigeria. Environmental Monitoring and Assessment, 184, 6449–6461.
[28] Maret, T.R., Cain, D.J., Mac Coy, D.E. & Short, T.M. (2003). Response of benthic invertebrate assemblages to metal exposure and bioaccumulation associated with hard-rock mining in northwestern streams USA. J. N. Am. Benthol. Soc., 22, 598–620.
[29] Gray, N.F. & Delaney, E. (2008). Comparison of benthic macroinvertebrate indices for the assessment of the impact of acid mine drainage on an Irish river below an abandoned Cu-S mine. *Environmental Pollution,* 155, 31-40.
[30] Clements, W.H. (1999). Metal tolerance and predator-prey interactions in benthic macroinvertebrate stream communities. *Ecological Application*, 9, 1073-1084.
[31] APHA (American Public Health Association). (2005). Standard methods for examination of water and waste water. American public Health Association, 874pp.

[32] Pennak, R.W. (1978). Fresh-Water Invertebrates of the United States. 2nd Edn., John Wiley and Sons, USA., ISBN-13: 9780471042495, Pages: 803.

[33] Merritt, R.W. & Cummins, K.W. (1996). An Introduction to the Aquatic Insects of North America. 3rd Edn., Kendall-Hunt, Dubuque, IOWA, pp: 862.

[34] Gerber, A. & Gabriel, M.J.M. (2002). Aquatic invertebrates of South African Rivers.Field Guide. Institute for Water Qualify Studies. Vol. I and II, pp: 150.

[35] Huxley, T. (2003). Provisional Atlas of the British Aquatic Bugs (Hemiptera, Heteroptera). BRC, NERC, Cambridge, pp: 118.

[36] Sabo, M. U., Wailare, M. A., Aliyu, M., Jari, S. & Shuaibu, Y. M. (2013). Effects of NPK fertilizer and spacing on growth and yield of watermelon (*Citrillus lanatus* L.) in Kaltungo local government of Gombe state, Nigeria. Scholarly journal of agricultural science, 3(80):325-330.

[38] Loska, K., Wiechuła, D. & Korus, I. (2004). Metal contamination of farming soils affected by industry. *Environment International. 30(2), 159–165.*

[40] Absalom, K.V., Egbere., O.J., Iwu, A.O., Folayanka, A.R. & Dashen., M. (2005). Coliform, Planktonic and Macro-invertebrates levels of River Delimi, Jos, Nigeria. *Journal of Aquatic Sciences.*Vol.20 (2) 131-138.

[41] Mariantika, L. & Retnaningdyah, C. (2014). The change of benthic macroinvertebrate community structure due to human activity in the spring channel of the source of clouds of Singosari sub-district, Malang Regency, *Jurnal Biotropika*, 2, pp. 254–259.

[42] Setiawan, D. (2009). “The study of macrozoobenthos community at downstream waters of Lematang river surrounding in Pasar Bawah, Lahar Regency,” *Science Research Journal*, 9, pp. 12–14, 2009.