Indian Journal of Ecology (2022) 49(2): 339-345
DOI: https://doi.org/10.55362/IJE/2022/3526

Manuscript Number: 3526
NAAS Rating: 5.79

Bioindicator Based Water Quality Assessment of Warbo and Dabo Streams in Awash Catchment, Dendi Woreda, Ethiopia

P. Sekhar
Environmental Science Department, College of Natural & Computational Sciences
Bule Hora University, Bule Hora, West Guji, Ethiopia
E-mail: saykhar999@gmail.com

Abstract: The present study was aimed at assessing the water quality of Warbo and Dabo streams in awash catchment using macroinvertebrates as biological indicators. The status of water quality was assessed in terms of presence or absence of indicator organisms in relation to physico-chemical parameters. Hilsenhoff Family-level Biotic Index (H-FBI) results have shown that the site 6 had relatively higher value (6.5) followed by site 5 (5.8). The site 1 recorded least H-FBI value which accounts for 3.2 followed by site 4 (3.74). For ETHbios index, highest score was recorded at site 3 (120) followed by site 4 (102) while the lowest score was obtained for the site 6 and site 1 which accounts for 54 and 57 respectively. The ASPT value was comparatively higher for sites 1 (6.67) and site 3 (6.31) than other sites. Principal components analysis of physico-chemical variables showed wide variation among the study sites. Axis 1 and axis 2 of the PCA explained 97.5% of the total variance regarding the sites versus physico-chemical association, where the first axis and second axis contributed 73.04% and 24.56% to the variation, respectively. Results of Pearson correlation reaveled that there exists significant relation between variuos pollutant parameters.

Keywords: Bio-indicators, ASPT, ETHbios, Macro invertebrates, Correlation

In most of the Sub-Saharan Africa, wetlands are under high pressure due to land use degradation, while they are increasingly being recognized as vital resources for achieving food security and rural livelihoods (Schuyt 2005). Aquatic bodies located in those areas receive all types of wastes from human activities including domestic, agriculture, industrial sources (Dixon and Wood 2003). In fact, land uses, and practices are probably the most important factors in determining the water quality. The direct and in direct effects of human activities are the major drivers of land use land cover change. Land use change is primary factor causing water quality and habitat degradation (Lakew and Moog 2015). Among the biological communities that are considered bio indicators of water quality, the most commonly used are the benthic macro invertebrates because they have several characteristics that make them easy to study and show clear responses when faced with adverse environmental conditions (Bonada et al 2006). Different groups of macroinvertebrates are excellent indicators of human impacts especially contamination (Kassahun et al 2013). The structure of the benthic communities in an aquatic ecosystem reflects its ecological conditions, including habitat heterogeneity and water quality (Burgmer et al 2007). The use of benthic invertebrate communities as indicators of environmental degradation or restoration has become widespread and reliable for bioassessment since the benthos broadly reflects environmental conditions. Most of them have quite narrow ecological requirements and are very useful as bioindicators in determining the characteristics of aquatic environments (Benetti and Garrido 2010). Intensive studies have been carried out on the impact of environment degradation especially due to pollution in various river systems in various parts of Ethiopia but studies related to land use impacts on the water quality on various streams of catchment area of Awash basin are very few or much limited. Hence in the present study an attempt has been made to assess the status of water quality of selected streams in Awash using benthic macroinvertebrates as bio-indicators of pollution. This study will help as a base line information on the major human induced land use practices and their effects on the water quality which in turn guide planners to take necessary steps to reduce further pollution of these streams.

MATERIAL AND METHODS

Study area and sites selection: The study area is in the Dendi Woreda of West Showa Zone of Oromia Regional state, Ethiopia (Fig. 1). The present study area is lying between latitude 40°28'E and 40°59'E and longitude, 9°99'N and 10°03'N with an altitude ranging between 2145 to 2464 msl. Study sites were selected based on their exposure to land use practices and various human activities such as agricultural practices, grazing, chemical fertilizers from the surrounding lands that pollute river basin (Table 1).

Accordingly, six sampling sites were selected which approximately cover 10- 12 km long with about 2-5 km apart from each other.

Measurement of physicochemical parameters: Water samples were collected from study sites for analysis of physico-chemical parameters and estimated using standard procedures (APHA 1999). All the samples were collected simultaneously along with the samples for macroinvertebrates analysis at same locations.

Benthic macro invertebrate sampling and analysis: For the collection of macro invertebrate from the selected sites, Multi-Habitat Sampling (MHS) scheme was implemented according to (Thomas et al 2010). Benthic macro invertebrates were collected using a standard hand net (625 cm^2, net mesh size 500 µm from multi-habitat units). Mega-lithal stones were sampled by brushing the surface approximately equal to the size of the sampling net. Macro-lithal stones were picked by hand and their surfaces were brushed to dislodge clingers and sessile organisms. Samples were then preserved in 4 % formaldehyde for further analysis with proper coding. Each sample was passed through a set of sieves of different sizes (5000, 3000, 2000, 1000 and 500 µm) to separate different size classes of macro invertebrate groups. Identification was done using South African Aquatic Invertebrates Identification key up to family level.

Water quality index (WQI): Water quality index of study sites was estimated using method described by (USEPA 2002).

Benthic macro invertebrate indices (BMI): Shannon and Weiner (1963) index was used to assess the diversity of macroinvertebrates in these rivers. Hilsenhoff Family of Biotic Index (H-FBI) (Hilsenhoff 1988) was calculated to assess the pollution tolerance of each collected taxa in each site. Other benthic macro invertebrate indices were used to evaluate abundance and pollution status of study sites according to (Lakew and Moog 2015).

Statistical analysis : Data collected for benthic macro

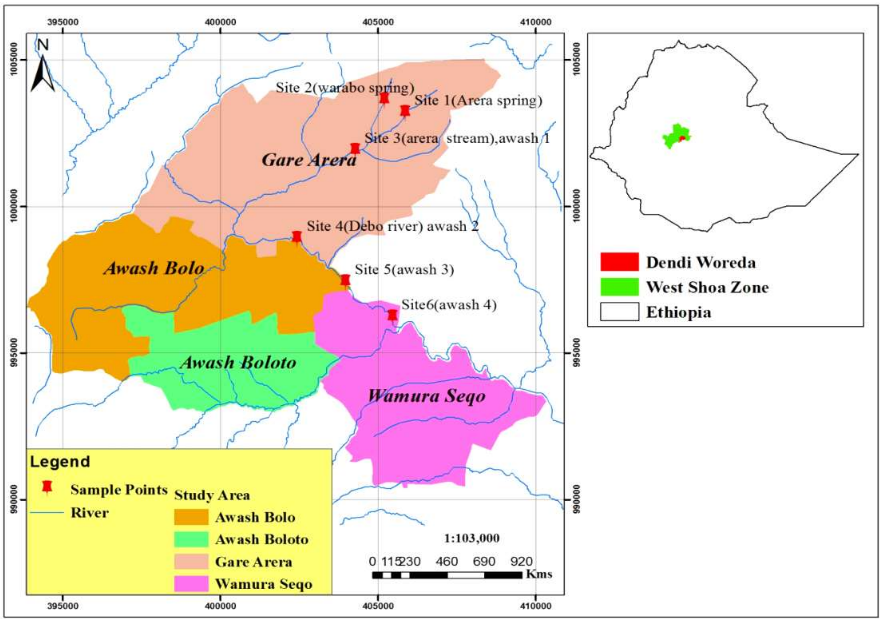

Fig. 1. Map of the study area & study sites

Table 1. Criteria for selection of study sites

Site ID	Characteristics of the site	Type of human intervention
S1	Arera spring from Arera stream	Less anthropogenic activities
S2	Warabo spring from Warabo stream	Moderate anthropogenic activities
S3	At confluence of the Warabo and Arera streams	Considerable anthropogenic activities
S4	Dabo stream	High anthropogenic activities and lack of canopy
S5	Located downside of Dabo stream after the bridge of the Ginchi town near to paper mill factory	Very high anthropogenic activities and direct discharge of effluents into the stream
S6	Located downstream of Awash River after the paper mill factory	Very high anthropogenic activities with discharge of effluents down stream

invertebrates and physico-chemical parameters were statistically analyzed by using Excel spread sheet and statistical software like SPSS version 21 (Statistical package for social science). Coefficient correlation was used to assess the significant relation between chemical and biotic parameters. Origin Pro 8.5 software was used to generate graphs. Multivariate analysis (Canonical Correspondence Analysis (CCA) was used to study the association between macro invertebrate abundance and physicochemical factors. Principal component analysis (PCA) was used to observe how sites varied with respect to physico-chemical variables or to observe the physico- chemical gradient along the sites using PAST software as the relation was unconstrained (Tar Barrk 1987).

RESULTS AND DISCUSSION

Minimum pH (7.98) was ats6, while the maximum (8.53) was at S4 with a mean value of 8.4 (Table 2). The mean pH level among the six sites having F-value 2.287 and p-value 0.112 implies there was no significance difference in pH level among the six sites. Clean water is an essential requirement for the establishment and maintenance of ecological integrity (Berger et al 2018). However, improper liquid waste discharge and solid wastes produced by human settlements and industrial activities leads to negative effect to human health and environment as pollution to river water source (Amble et al 2013). pH is an important variable in ecological water quality assessment as it influences many biological and chemical processes within the water body and influenced by various factors and processes including temperature, discharge of effluents, runoff, acidic perception, microbial activity. The minimum pH was recorded at S6 (7.89) might be explained due to anthropogenic activities such as waste discharge, cloth washing and open bathing as observed. The highest value (8.62 mg L^{-1}) of dissolved oxygen was recorded from site S4, which is under the agricultural land use, while the lowest values 6.32 and 6.39 mg L^{-1} were recorded from site, S3 and S1 respectively under forest land use. At site S6 (at downstream of paper mill), the dissolved oxygen concentration was found to be 6.46. The mean comparison of DO concentration among the six sites indicated that there was a significance difference in DO level. The BOD values of study sites ranged from 0.51 mg L^{-1} to 2.38 mg L^{-1}. The considerable variations in DO and BOD values can be attributed to the level of impact of anthropogenic activities among the study sites. The maximum concentrations of NH4^{+H} (0.49 mg L^{-1}) was recorded from site, S1, which was under forest land use while the minimum concentration (0.07 mg L^{-1}), was recorded for the site, S6$_{,}$ under urban land use. The mean comparison of NH4^{+H} concentration among the six sites indicated there was no significance difference in NH4^{+H} concentration among the six sites. The maximum NO$^{-}_{3}$ concentration (0.97 mg L^{-1}) was in the forest and agricultural land use, site S3, while the minimum (0.210 mg L^{-1}) was in site, S5 and there was no significance difference in NO$^{-}_{3}$ concentration among the six sites. It was expected that nitrate nitrogen concentration would be more in site S6 due to discharges of paper mill effluent, but the low values were observed and this was possibly due to denitrification process of microbial communities. The maximum PO$_4^{3-}$concentration (0.05 mg L^{-1}) was for the samples collected from S2 while the minimum (0.03 mg L^{-1}) was for water samples collected from S1. The mean comparison of PO$_4^{3-}$ concentration among the six sites 2 implies that there was no significance difference in PO$_4^{3-}$ concentration among the six sites. The PO$_4^{3-}$ in the studied area was possibly from the agricultural land use might be due to use of phosphate fertilizers in agricultural fields and animal manure. There exists significant relation between variuos pollutant parameters (Table 3). PO$_4^{3-}$ showed a strong positive correlation with pH, BOD and NO$^{-}_{3}$ but not significant at 0.05 level. Dissolved oxygen and BOD showed a very strong negative correlation which is significant at 0.05 level. Both DO and BOD showed a strong negative correlation with NO$^{-}_{3.}$

An attempt has been made to assess the water quality status of study sites using water quality index (Fig. 2) which indicate about cumulative effect of various chemical pollutants on water bodies. In the present study sites S1, S3 and S2, S4 showed equal water quality indexes of 65 and 64

Table 2. Physico-chemical analysis of study sites

	Minimum	Maximum	Mean	Std. Deviation	P-value
PH	7.98	8.53	8.4050	.21548	0.112
DO	6.32	8.62	7.2767	1.06566	0.000
BOD	.51	2.38	1.2683	.64179	0.000
NH_4^+	.07	.49	.2567	.15122	0.055
NO^-_3	.21	.93	.5400	.30424	0.056
PO_4^{3-}	.03	.05	.0367	.00816	0.292

respectively. The least water quality index was obtained with site S5 (61) which is near to a paper mill factory. The highest water quality index was recorded at site S6 (68) which is situated at downstream of paper mill factory. Even though site 6 is under intensive pressure from human activities, the comparative high-water quality obtained may be attributed to factors such as self-purification capacity and distance of sampling point from the source of pollution. The water quality of all the study sites was considered to be of medium quality as evident from WQI analysis.

Analysis of relation between indicator organisms and water quality of the study sites clearly indicated that water quality has a strong influence on presence or absence of indicator organisms as shown in (Fig. 3-5).

Composition and abundance of invertebrate: During the study period a total three classes (Oligochaeta, Insect and Gastropod), 10 orders and 37 families of macro invertebrate were identified from the six study sites (Fig. 6). There were 7 orders of the class Insecta namely Plecoptera, Ephemeroptera, Odonata, Hemiptera, Trichoptera, Coleoptera and Diptera. The nymph and larva stage of the insects identified belongs to 33 families, while Gastropoda and Oligochaeta were the non-insect macro invertebrates representing 4 families. The order Diptera was represented

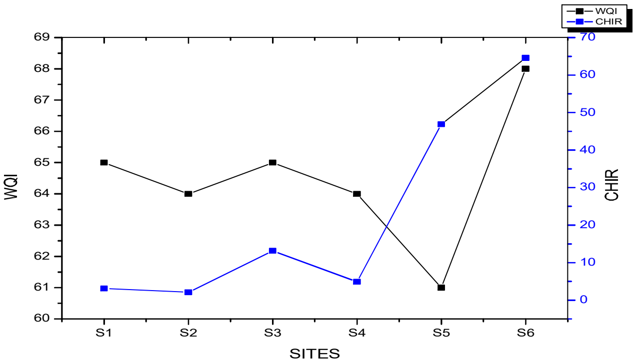

Fig. 3. Effect of water quality index on CHIR in study sites

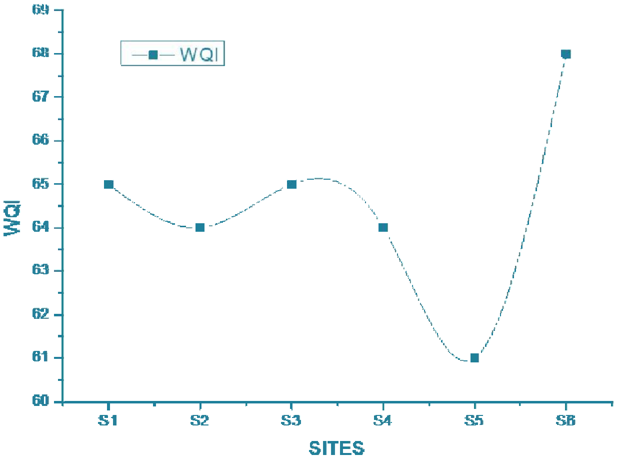

Fig. 2. Water quality index of the study sites

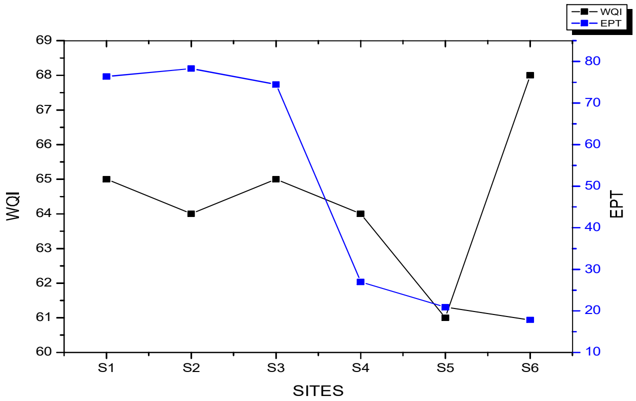

Fig. 4. Effect of water quality index on EPT in study sites

Table 3. Correlation matrix of physico-chemical parameters

		PH	DO	BOD	NH3	NO3	PO4
PH	Pearson Correlation	1	.492	.246	.412	.095	-.102
	Sig. (2-tailed)		.321	.638	.416	.859	.847
DO	Pearson Correlation	.492	1	-.858*	-.343	-.809	.164
	Sig. (2-tailed)	.321		.029	.506	.051	.756
BOD	Pearson Correlation	.246	-.858*	1	-.233	-.820*	-.001
	Sig. (2-tailed)	.638	.029		.657	.046	.998
NH3	Pearson Correlation	.412	-.343	-.233	1	.590	-.643
	Sig. (2-tailed)	.416	.506	.657		.217	.169
NO3	Pearson Correlation	.095	-.809	-.820*	.590	1	-.105
	Sig. (2-tailed)	.859	.051	.046	.217		.844
PO4	Pearson Correlation	-.102	.164	-.001	-.643	-.105	1
	Sig. (2-tailed)	.847	.756	.998	.169	.844	

*. Correlation is significant at the 0.05 level (2-tailed).

by 8 families constituted (22 %) of the total fauna and Trichoptera formed (16%), followed by Coleoptera (13%), and Ehpemeroptera (13%). Odonata and Hemiptera each accounted for 11 % and Gastropoda accounted for 8%. Both Plecoptera and Oligochaeta accounted for 3% each.

Benthic Macroinvertebrate Indices (BMI) and Spatial diversity: Comparison of benthic macro invertebrates among six study sites showed considerable variation in spatial diversity (Fig 7). The percentage of dominant taxa (%DT) increased from least impacted site 2 to the more impacted site 6 and also site 2 had the highest abundance of benthic macro invertebrates followed by site1 and regarding the diversity and species richness site 4 had the highest number of species diversity and richness. The percentage of Ephemeroptera, Heptageniidae and Plecoptera (EPT) increased from more impacted site to least impacted sites. The percentage of chironomidae decreased from more impacted site to least impacted site. In the study area, the river was subjected to human influenced factors such as agricultural activities, grazing and urbanization (discharge of paper mill wastes. Luo et al (2017) correlated water quality deterioration with lack of proper soil and water conservation

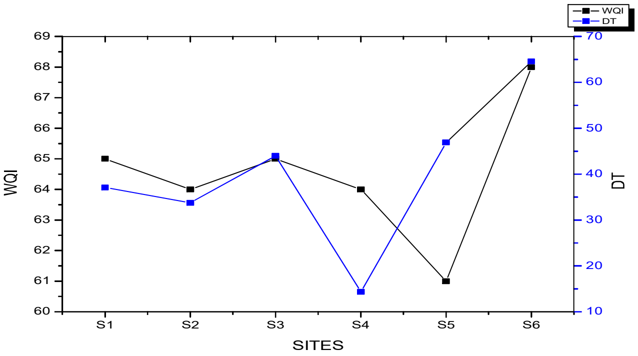

Fig. 5. Effect of water quality index on DT in study sites

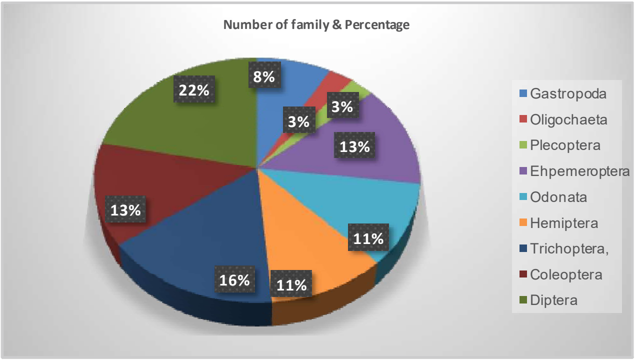

Fig. 6. Macroinvertebrate families and their percentage of occurrence

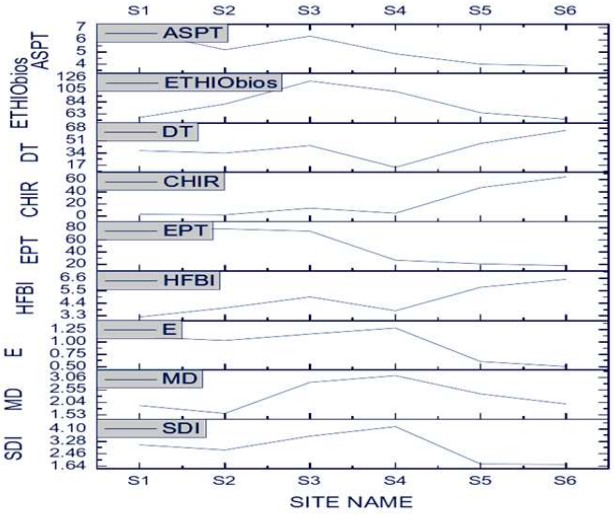

Fig. 7. Macroinvertebrate families and their spatial diversity

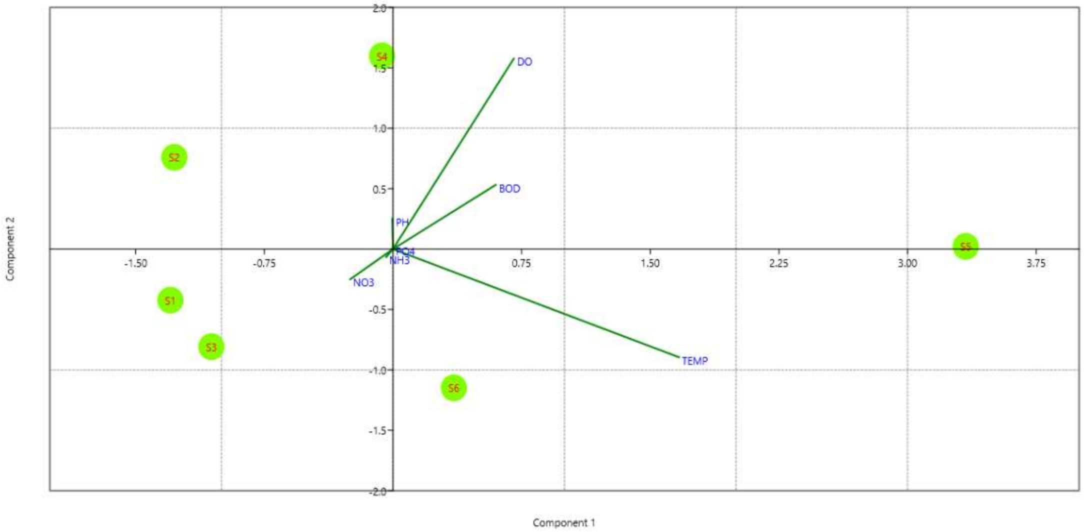

Fig. 8. PCA analysis of the physicochemical factors

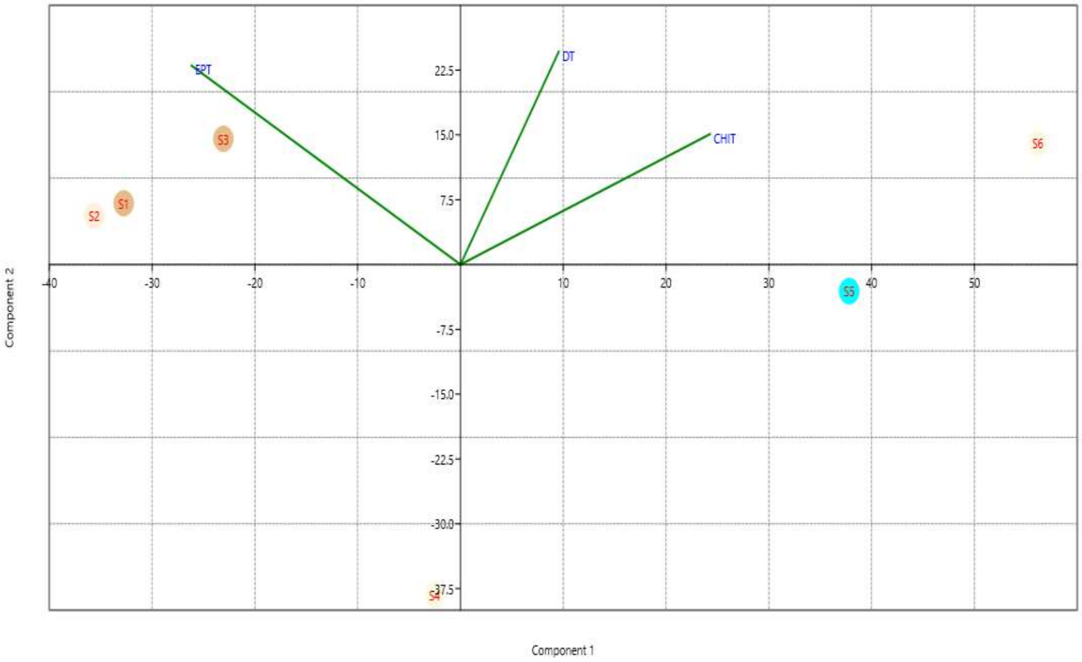

Fig. 9. PCA analysis of macroinvertebrate families and their spatial diversity

measures, high number of cattle grazing, deforestation, and siltation, conversion of forest land into farmlands and effluent discharge from factories. In the study area, benthic population showed an inverse relationship with anthropogenic activities that the macro invertebrates declined correspondingly with the increase in anthropogenic activities. This study agrees with the findings of Berger et al (2018). Results of present study revealed that as habitat and water quality are degraded, number and percentage of EPT decreased, while percentages of Diptera and blood red chironomids increased.

Variation in physico-chemical variables among sites: Principal components analysis of physico-chemical variables showed wide variation among the study sites (Fig. 8). Axis 1 and axis 2 of the PCA explained 97.5 % of the total variance regarding the sites versus physico-chemical association, where the first axis and second axis contributed 73.04% and 24.56% to the variation, respectively. Highest temperature, BOD and DO are strongly associated with site 5. High nitrate contents are positively associated with site 3 and ammonia is strongly correlated with site 1.

Variation in macro invertebrate assemblages among sites: PCA analysis of macro invertebrate taxa in study area indicated that CHIR and DT is strongly associated with site S6 and S5 whereas DT is strongly associated with site S3 (Fig. 9).

CONCLUSION

Based on foregoing analysis, it was clearly shown that water quality of streams in awash catchment was directly correlated with human influences and in turn affected the distribution of benthic macroinvertebrate community. The mean of pH, PO_4^{3-} NO_3^{-}, $NH4^{+H}$ were among the six sites had no significance differences in the study area and the mean T, DO, EC, BOD_5 were had a significance difference among the six sites. The percentage of dominant taxa was increased from least impacted site to the more impacted sites. Site 2 had the highest abundance of benthic macro invertebrates followed by site 1. The percentage of Ephemeroptera, Heptageniid and Plecopteran (EPT) increased from more impacted site to least impacted sites. The percentage of chironomidae decreased from more impacted site to least impacted site. The H-FBI values were significantly lower at the upper stream and higher at downstream of the study areas.

REFERENCES

APHA 1999. *Standard methods for examination of water and wastewater,* 20th edition, American Public Health Association, New York, USA.

Arimoro FO and Muller WJ 2010. Mayfly (Insecta: Ephemeroptera) community structure as an indicator of the ecological status of a stream in the Niger Delta area of Nigeria. *Environmental Monitoring* and *Assessment* **166**: 581–594.

Beneberu G, Mengistou S, Eggermont H and Verschuren D 2014.

Chironomid distribution along a pollution gradient in Ethiopian rivers, and their potential for biological water quality monitoring. *African Journal of Aquatic Science* **39**: 45-56.

Benetti CJ and Garrido J 2010. The influence of stream habitat and water quality on water beetles' assemblages in two rivers in northwest Spain. *Vie et milieu* **60**(1): 53-63.

Berger E, Haase P, Schäfer RB and Sundermann A 2018. Towards stressor-specific macroinvertebrate indices: Which traits and taxonomic groups are associated with vulnerable and tolerant taxa. *Science* of the *Total Environment* **619-620:** 144-154.

Bonada N, Prat N, Resh VH and Statzner B 2006. Developments in aquatic insect biomonitoring: A comparative analysis of recent approaches. *Annual Review of Entomology* **51**: 495-523.

Burgmer T, Hillebrand H and Pfenninger M 2007. Effects of climate-driven temperature changes on the diversity of freshwater macroinvertebrates. *Oecologia* **151**: 93-103.

Dixon AB and Wood AP 2003. Wetland cultivation and hydrological management in Eastern Africa: Matching community and hydrological needs through sustainable wetland use. *Natural Resources Forum* **27**: 117-129.

Hilsenhoff WL 1988. Rapid field assessment of organic pollution with a family level biotic index. *Journal of North American Benthological Society* **7**(1): 65-68

Kassahun A, Fekadu T and Zenebe T 2013. Adaptability, growth and reproductive success of the Nile tilapia, *Oreochromis niloticus L.* (Pisces: Cichlidae) stocked in Lake Tinshu Abaya, South Ethiopia, *Journal* of *Biological Sciences* **10**: 153-166.

Lakew A and Moog O 2015. Benthic macro invertebrates based new biotic score “ETHbios” for assessing ecological conditions of highland streams and rivers in Ethiopia. *Limnologica* **52**: 11-19.

Luo K, Hu X, He Q, Wu Z, Cheng H, Hu Z and Mazumder A 2017. Impacts of rapid urbanization on the water quality and macroinvertebrate communities of streams: A case study in Liangjiang New Area, China. *Science* of the *Total Environment* **621**: 1601-1614.

Perry JB 2005. Biotic indices of stream macro invertebrates for fun and (educational) profit. *In: Tested studies for laboratory Teaching* (M. A. O'Donnell, Editor). pp 281-294. Proceedings of the 26th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), WI, USA.

Riens J, Schwarz M and Hoback W 2013. Aquatic macroinvertebrate communities and water quality at buffered and non-buffered wetland sites on federal waterfowl production areas in the Rainwater Basin, Nebraska. *Wetlands* **33**: 1025-1036.

Schuyt KD 2005. Economic consequences of wetland degradation for local populations in Africa. *Ecological Economics* **53**(2): 177-190.

Ter Braak CJE 1987. The analysis of vegetation environmental relationships by canonical correspondence analysis. *Vegetation* **69**: 69-77.

Thomas K, Abdul Basar MB, Thomas O, Otto M, Subodh S and Daniel H 2010. Assessing river ecological quality using benthic macroinvertebrates in the Hindu Kush Himalayan region. *Hydrobiologia* **651**: 59-76.

USEPA 2002. *Methods for Evaluating Wetland Condition: Introduction to Wetland Biological Assessment Office of Water Quality*, U.S. Environmental Protection Agency, Washington, DC: EPA-822-R-02-014

Wetzel RG 2001. *Limnology: Lake and River Ecosystems.* Academic Press, *San Diego* USA: p 1006

WHO 2017. *Guidelines for Drinking-water Quality*. Fourth Edition ed. Brazil.

Received 18 November, 2021; Accepted 21 December, 2021