International Research Journal of Environmental Sciences ISSN 2319–1414
Vol. **9(1),** 69-77, January **(2020)** *Int. Res. J. Environmental Sci.*

Case Study

Assessment of downstream pollution influence of urbanization on stream physicochemical characteristics and Macroinvertebrate community structure: in case of Woliata Sodo Town, Ethiopia

Hussen Yasin[1*], Biniam Asfaw[2] and Eyasu Chama[2]
[1]Departments of Biology, Werabe University, Ethiopia
[2]Departments of Biology, Wolaita Sodo University, Ethiopia
hussenyasin88@gmail.com

Available online at: www.isca.in, www.isca.me
Received 27th April 2019, revised 9th July 2019, accepted 11th September 2019

Abstract

Woliata Sodo Town ($6^0$48'N to $37^0$47'E) is an important commercial town in southern region, Ethiopia. The aim of the present work was to assess the downstream pollution influence of Sodo Town on water quality and macroinvertebrate community structure. Among four sampling sites, three sites were at downstream of the town whereas a reference site was at upstream. Physicochemical data with sample of macroinvertebrates was taken at upstream, midstream and downstream of the sampling sites from September to January 2016/17. Water quality test including temperature, electrical conductivity, TDS and salinity were measured in-situ and the recorded result in ranges 7.385 to 8.46 pH meters, 20.25 to 22.28 ˚C, 104.38µS/cm to 280µS/cm, 71.73mg/L to 203.25mg/L and 0.07ppt to 0.17ppt, respectively. A total of 3927 individuals belonging to 15 families in different orders including Diptera (97%), Ephemeroptera (1.3%), Hemiptera (0.35%), odonata (0.3%), Coleoptera (0.28%), and other non-insect taxa comprising (0.5%) were recorded. Dipterans were the most abundant taxon. Family Chironomidae alone in this order has an abundance of 89.8% of the total count which is highest in downstream sites. Somewhat, good water quality in station one is manifest by the presence of pollution sensitive taxa. Whereas, poor water quality in downstream specifies by enormous pollution tolerance macroinvertebrate abundance like blood-red chironomidae. So in the study area the various disturbances like mismanagement of Abattoir effluent and other anthropogenic activities should not be overlooked.

Keywords: Downstream, pollution, macroinvertebrate, tolerance, water quality, Woliata sodo.

Introduction

Expansion of urban land causes a various range of watershed modification that affects the physical, chemical, and biological assets of streams[1]. Improper urban land use on catchment area of water bodies deteriorate aquatic ecosystem in downstream; the change is very rapid and difficult to reverse or correct[2].

All over the world, human populations are attracted alarmingly towards urban, about fifty percent of the world's population at this time dwelling in urban areas[3]. Rivers in urban area play great roles in affording water resources for the inhabitant and environment survival. However, across the globe it is confronting a number of problems with regard to the accessibility and sustainability of freshwater resources. As consequence, this may leads in serious threats for current and coming generations of humanity and also for ecosystems at large[4].

Humans may contaminate water body through different means viz., chemical contamination, physical contamination and biological contamination by introducing alien species that amend the habitat of aquatic biota. Unlike abiotic component, the biotic component of aquatic ecosystem is susceptible to all forms of pollution[5]. Environmental alteration or pollution can change ecosystem. Improper human activities on watershed may lead rise of the turbidity of water. This may affect the light penetration for photosynthesis in water and may lead a raise of the temperature of the water. Runoff from urban area is one of non-point sources pollution to aquatic ecosystems.

Urban runoff consists of main pollutant in the form of suspended solids and excess nutrients which can deteriorate the wellbeing aquatic ecosystem[7]. Nowadays urbanization and industrialization generates various diffuse sources of pollution which affect quality of water[8]. High load nutrient from inorganic fertilizer in the form of nitrogen and phosphorus can trigger extreme algal growth or algal blooms.

The decomposition of these algal materials can generate toxins and suffocated environment for aquatic life. Toxin materials can also come into water bodies from industrial and agricultural wastewater and can comprise such substances as pesticides and heavy metals[9].

In urban areas of most developing countries, the wastes emanated from point sources such as industrial, municipal, clinical and any other types of liquid damp directly into water body without any treatment. They are also discarding the solid wastes with different constituents from inhabited areas at side of street including open air urination. The condition is not different in case of Ethiopia where organic wastes from residential, agricultural and industries are directly damped into rivers and streams[10]. Hence, developing easily appropriate biological monitoring system for evaluation of aquatic ecosystems is very critical.

Methodology

Area of study: *Woliata Sodo town is an important commercial town in southern Ethiopia.* It is the capital town of Wolayta zone administration (Figure-1). Sodo is situated at the foot of mount *Damot*, which is the prominent peak in the study area with 2950m high a.m.s.l. The geographical location of the town is extended over $6^0$48'30" N to $6^0$53'00" N latitudes and 37^0 43' 30"E to $37^0$47'30"E longitudes with altitude over 1800m to 2500m amsl. Numbers of permanent and seasonal streams originated from the foot of mount Damot which disseminate into the town in different parts. Among them the main ones include; *Hamassa, Kalte, Kokate, Bichere, Lintala*, *Waja* river, etc. The study region is demarcated in the west and east with two permanent rivers (*Hamassa* and *Waja* River). Most of the rivers are intermittent in nature during dry season except *Hamasa* and *Waja* rivers, which drain into Lake Abaya. As the town is situated at higher elevation, the flood hazard risks remain common and serious in damage particularly during rainy seasons[11].

Sample site selection: Kalte sream was purposely selected to describe the negative impact of the town on stream health. This is because of the waste of different activities in the town including the town's great commercial center that is Merkato as well as slaughter house dump their waste directly to the stream. Kalte stream stretches approximately 3km from main road along the northeastern part of Sodo Town.

It originates from the mountainous areas of the province and run through some parts of Sodo town and traverses the rural agricultural land and finally by mix with other rivers it empties into the lake Abaya. The riparian vegetation consists of grasses and shrubs with some trees surrounding the area of the stream.

A preliminary survey of study area was done for one day to select appropriate sites for sample collection based on the access and potential sources of pollution. Four sites were selected along the Kalte stream which flows along north eastern portion of Sodo town by crossing asphalt road of the Ottona Referral Hospital. Station one (upstream, S_1) is along the vicinity of semi-rural area at upper part of the town; station two (midstream, S_2) which is approximately 500m from the station one; station three (S_3, downstream) 500m from station two where detrimental pollutant particularly from town's principal abattoir like blood and abdominal wastes without any treatment dump to the stream and station four (S_4, further downstream) found approximately 500m from station three. Therefore, S_1 was assigned upstream of the town where less anthropogenic impact seen whereas S_2, S_3, and S_4 were parts of stream sections that lie along the town but with different characteristics.

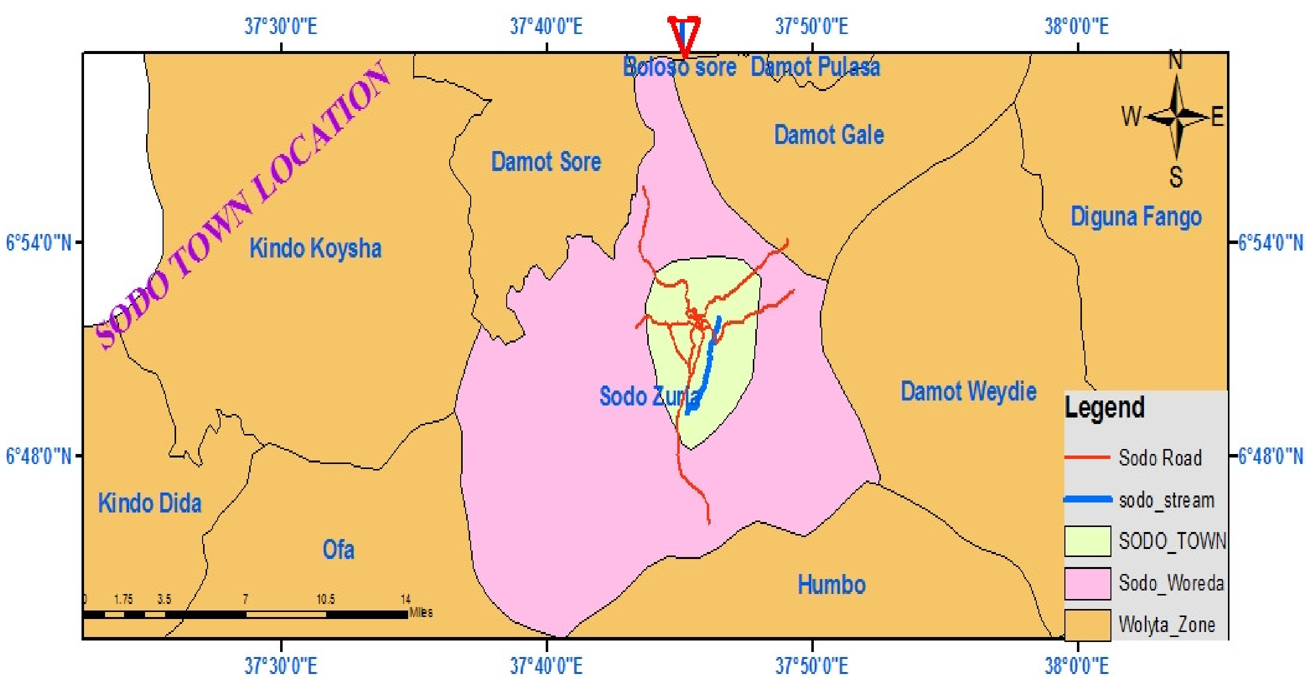

Figure-1: Map of the study area.

Sampling procedures and programs: Data of water quality were taken together with the sample of macroinvertebrate during September to January 2016/17 from the study area. The water quality data measured during sampling includes pH, temperature, total dissolved solids, electrical conductivity and salinity. The measurement was carried out using combine Cond/TDS/Sal/Resi meter (Model: SX713) and pH measured by using portable pH meter (model: pH- 013).

Data of macroinvertebrates were collected using kick net from four sampling sites. Kick net is designed to take a sample of 1 m^2 of substrate at once and able to sample any depth from a few centimeters to just beneath 1m[12]. The net was situated facing the upstream and a sample collector disturbed the area upstream at a distance about one meter. It was lifted out of the water with a forward scooping motion to prevent any of the organisms captured to wash away. Macroinvertebrate samples were separated from other debris using sieves of different mesh size. Then the sample was preserved in 70% ethyl alcohol and identified up to family level using the reference guide of *Bouchard*[13].

Data Analysis: Data of water quality and macroinvertebrates were subjected to statistical analysis. Descriptive statistics were used for each of the water quality variables. To estimate the diversity, evenness and correlation to environmental factor at each sampling site, multivariate statistical package and pearson correlation analysis were employed. All calculations, statistical analysis and descriptive diagram were calculated and drawn up by using Microsoft Excel spread sheet.

Results and discussion

Data of water quality: The mean pH concentration observed in study area along Kalte stream ranged from 7.385±1.49 to 8.46±0.76. This value is not out of the standard for aquatic ecosystem. The mean temperature ranged from 20.25±0.96 to 22.28 ± 0.53 (Table-1). As a result of several factors pH value of water body can be fluctuated such as dumping waste, exposure to atmospheric air, biotic action and temperature changes. In addition to sunlight, temperature of water inputs, heat exchange from atmosphere and heat gain or loss by evaporation or condensation affect temperature of freshwater body[14].

In the study area the least conductivity mean value 104.38µS/cm and highest mean value 280µS/cm at station one and station three, respectively (Table-1). The smallest value of EC was recorded at s station one, which is originated from rural side of the Town. Conductivity can be affected by discharges to water that may be dependent on the nature of the discharge. Maximum value of this parameter implies that the occurrence of higher amount of dissolved salts of cation in the form of calcium, magnesium and sulphate from the catchment area during the rains[14].

Table- 1: Observed value of physicochemical parameters of water with (Mean ± SD) in four sampling times (T_1, T_2, T_3 and T_4) during 2016-2017 at study area (temperature in ˚C, pH in pH meter, TDS in mg/l, conductivity in µS/cm and salinity in ppt).

Parameters	Site 1					Site 2				
	T_1	T_2	T_3	T_4	Mean± (SD)	T_1	T_2	T_3	T_4	Mean± (SD)
Temperature	21.8	22.3	22	23	22.28 ± 0.53	21.5	22	23	21	21.88 ±0.85
pH	5.5	8	9	7.04	7.385±1.49	7.5	8.18	9	9.14	8.46±0.76
TDS	65	86.4	86	49.5	71.73±17.84	124	209	234	129	171.75±54.83
Conductivity	96	125	125	71.4	104.38±25.86	215	314	356	167	263±87.12
Salinity	0.05	0.14	0.06	0.02	0.07±0.05	0.1	0.14	0.16	0.09	0.12±0.03
	Site 3					Site 4				
	T_1	T_2	T_3	T_4	Mean± (SD)	T_1	T_2	T_3	T_4	Mean± (SD)
Temperature	19	21.8	22	21	20.95±1.37	19	20	21	21	20.25±0.96
pH	6.5	8	7	9	7.63±1.11	7.1	8.2	7	8.5	7.7±0.76
TDS	175	240	255	139	203.25±54.62	220	112	313	47.4	173.4±117.4
Conductivity	250	355	310	205	280±65.95	328	167	468	60.4	255.85±179.17
Salinity	0.13	0.16	0.17	0.11	0.14±0.03	0.16	0.08	0.21	0.22	0.17±0.06

TDS value in study area ranged with mean value 71.73±17.84mg/L to 203.25±54.62mg/L at station one and station three, respectively (Table-1). The highest value of TDS was recorded at station three, which is found at the abattoir waste dump directly to the stream. The solubility of rocks and soil in catchment area is the main factor that affects TDS values of water[15]. The salinity in study area with mean value ranged from 0.07 to 0. 0.17ppt. Salinity is high at station four with mean value 0.17±0.06 (Table-1). The quality of water for different purpose such as for irrigation or drinking can be influenced by content of salts and other substances. Aquatic biota also influenced by these substances because of salinity tolerance for every kind of organism varies from specie to species[16].

Macroinvertebrate community structure: *A* total of 3927 macroinvertebrates, representing 6 orders and 15 families were recorded. Insects were the dominant group with 14 out of the 15 identified taxa. The Diptera and Coleopteran were the diverse order each with 5 families; followed by Ephemeroptera with three families; Hemiptera with two families; Odonata with one family and non-insect taxon like Nematoda were recorded (Table-2).

During the study period, community balance of macroinvertebrates was estimated. This showed Diptera (97%), Coleoptera (0.28%), Ephemeroptera (1.3%), Hemiptera (0.35%), odonata (0.3%), and other non-insect taxa comprising (0.5%). Dipterans were the most abundant taxon with 97%. They were present in high number in the downstream site (site 3). Chironomidae alone in this order has an abundance of 89.8% of the total count which is higher than the percentages of other orders indicating that this family was responsible to increase the total count of macro invertebrates (Figure-2).

Table-2: Number of Macroinvertebrate collected from study site in 2016/17.

Order	Taxon	Pollution	Study site				
	Order/Family	Tolerance (TV)	S_1	S_2	S_3	S_4	Total
Ephemeropter	Baetidae	4	40	7	1	0	48
	Baetiscidae	3	1	0	0	0	1
	Caenidae	7	2	1	0	0	3
Odonata	Coenagrionidae	9	12	0	0	0	12
Diptera	Syrphidae	10	2	56	17	67	142
	Chironomidae	8	936	857	1356	376	3525
	Culicidae	8	37	37	6	69	149
	Tabanidae	6	1	0	0	0	1
Coeoptera	Hydrophilidae	5	4	0	0	2	6
	Gyrinidae	4	3	0	0	0	3
	Dryopidae	5	1	0	0	0	1
	Elemidae	4	0	1	0	0	1
Hemiptera	Notonectidae	8	10	0	0	0	10
	Nepidae	8	4	0	0	0	4
Other non insect Taxa	Nematoda	6	18	1	2	0	21
	Total number of Individual		1071	960	1382	514	3927
	Number of Taxa		14	7	5	5	

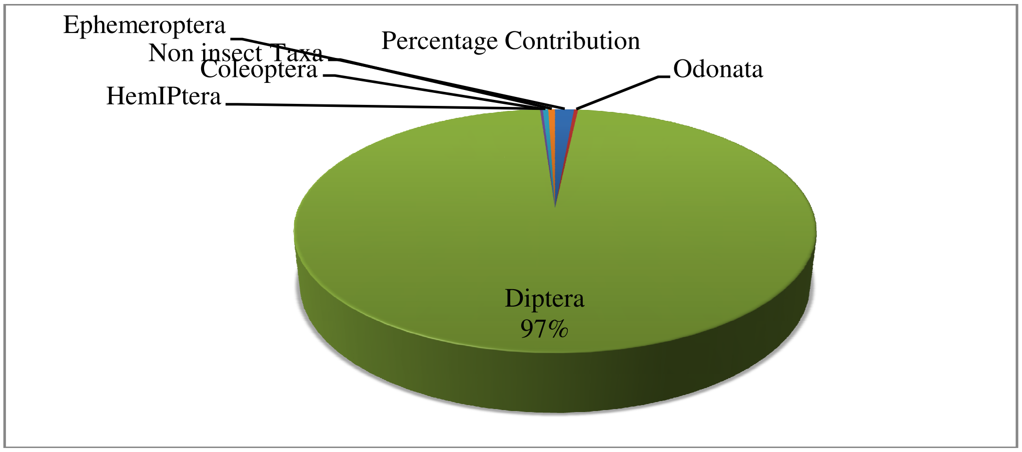

Figure-2: Percentage of individual abundances collected from each taxon.

Downstream influence of urbanization on Macroinvertebrate communities of stream: The downstream effects of urbanization on macroinvertebrates communities were evaluated by comparing total abundance, total taxa richness, % Ephemeroptera, %EPT taxa richness, community loss index, percent of dominant taxa, and abundance of ratio Ephemeroptera to Chironomidae. Tolerance and species richness index like FBI and shanon-weiner index. An integral component of any biomonitoring program depends on the selection of appropriate metrics and the close relationships between water chemistry and benthic macroinvertebrate community[17].

Table-3: Metrics score of macroinvertebrate communities at each sampling site (S_1, S_2, S_3 and S_4).

Metrics	Scores (S_1)	Scores (S_2)	Scores (S_3)	Scores (S_4)
%Taxa richness	93.3%	46.7%	33.3%	33.3%
%Ephemeroptera	81.1%	15.1%	1.9%	1.9%
%EPT	81.1%	15.1%	1.9%	1.9%
%Blood red chironomide	26.6%	24.3%	38.5%	10.7%
%Dominant taxa	91.1%	99%	99.8%	99.4%
***EPT/C	3.1	0.62	0.1	0.2
Shannon-Diversity Index	1.06	0.68	0.16	‘1.14
**CLI	0	1.1	1.8	1.8
* FBI	7.81	8.09	8.02	8.25

***Ratio of EPT and Chironomidae, **CLI- community loss index, *FBI- Family Biotic Index.

There is considerable ordering of sites downstream of the urban effluent, indicating that the impact is intense at downstream sites just at and below the abattoir effluent. Sites 3 and 4 that found further downstream to the urban area could possibly be considered as impaired based on taxonomic composition and structure. Furthermore, these sites showed considerable differences from reference site based on some biological parameters like % taxa richness, % EPT, % Chironomidae, % dominant taxa, % Ephemeroptera, CLI and also based on measured water quality parameters of the stream. So, the result of this study showed that the impacted sites were dominated by the Dipterans, particularly by family chironomidae. Whereas the non-impacted reference site was relatively dominated by Mayflies which is stress sensitive group (Table 3). The response of macroinvertebrates to pollution varies from one species to another, this characteristic made them unique in biomonitoring. So macroinvertebrates are very difference in their degree of tolerance towards pollution, some species can endure poor water quality whereas others are very sensitive can only survive clean water. So this makes macroinvertebrates preferable biomonitoring tools for ecosystem assessments[18]. Physical, chemical and biological characteristics of water body influence the distribution of aquatic macroinvertebrates. For these conditions of water some of them are sensitive while others are tolerant. This characteristic of aquatic macroinvertebrates made them good pointer of stream health[19]**.**

Taxa richness: The highest percentage taxa richness of macroinvertebrate was found at the reference site, station 1 (Figure-3). A high diversity of organisms is considered as a sign of good water quality. More diversity in a sample implies higher taxa richness. Unlike taxa richness other metric measures the amount of population made by one type of organisms which is describe as Percent dominance. So, low percent dominance also describes more diversity[18].

High taxa richness in the reference Site (S_1) indicates that taxa accumulation would increase in non-impacted sites (Figure-3). However, highest abundance by individual count could have been collected in the impacted station of the streams due to pollution that would lead to lower taxa richness. Macroinvertebrates are good indicators of condition of aquatic ecosystem due to their ubiquitous nature and their sensitivity to environmental stressor. So they serve as a stream and watershed health indicator based on the biological integrity of a stream[20].

As a result of environmental stressor, the benthic-macroinvertebrate community in impacted site may be disturbed and noticeably altered from a non-impacted site. It is dominated by pollution tolerance macroinvertebrate such as chironomidae and oligochaetes while sensitive macroinvertebrate including mayflies and stoneflies are rare, and caddisfly taxa may be limited[21].

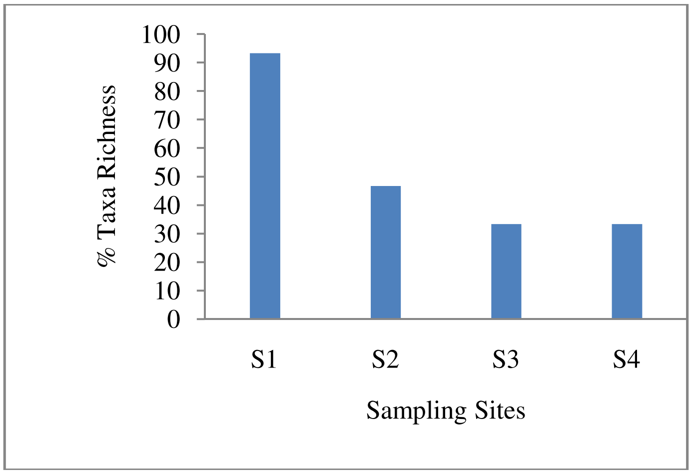

Figure-3: Taxa richness of macro invertebrate in the reference (S_1) and other downstream sites.

Percent of Ephemeroptera: In this study high abundance of Ephemeroptera (mayfly) was recorded from reference site one (Figure-4). Pollution sensitive taxa like mayfly are mostly accepted as bioindicators to monitor running water for pollution[22]. Expositions to enviromental stressor affect mayfly taxa richness in low land areas than in highland hilly mountainous region[23].

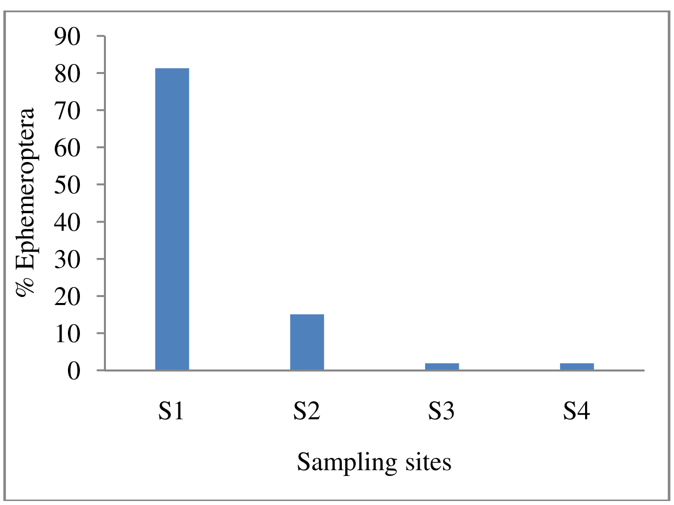

Figure-4: Percentage of Ephemeroptera at the reference site (S_1) and other downstream sites.

Percent of EPT: In this study, %EPT was almost none at disturbed sites (Figure-5). These results indicate that many EPT taxa will disappear in the presence of severe pollution. Due to enviromental factor like physical and chemical stressors there will be consistent change in any of the biological communities from sensitive invertebrate species to species that are more tolerant. Pollution sensitive macroinvertebrate taxa comprising Ephemeroptera, Plecoptera and Trichoptera collectively known as EPT are considered as good indicators of water quality[24]. As the quality water degrades, fewer of these species are found in the river[18].

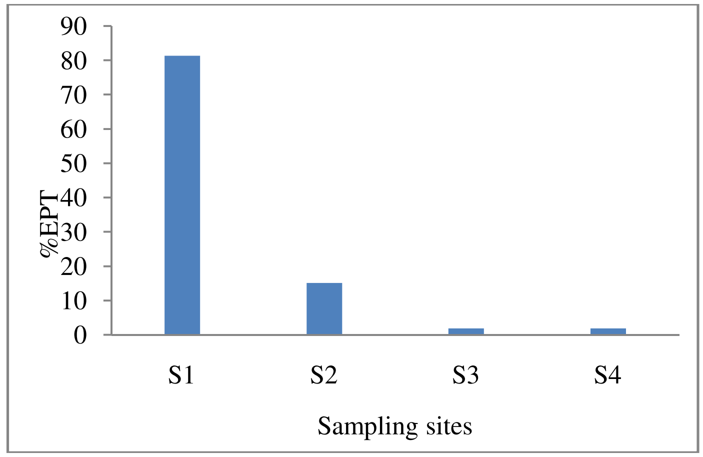

Figure-5: Percentage of EPT in the reference site (S1) and other downstream sites.

Percent of Dominant Taxon: In the study area, dipterans were dominant taxon in the sites that lie downstream of the urban area (Figure-6). As a result of environmental stressor like pollution at impacted site, the community structure of benthic-macroinvertebrate is disturbed and noticeably altered. Therefore, pollution sensitive species are rare and limited, while "pollution tolerant" and facultative organisms are dominated the community[25].

Figure-6: Percentage of dominant taxon in the reference site (S1) and downstream sites.

Percent of Chironomidae (%CHIR): The highest percentage of chironomidae was recorded from the downstream at site three; while in the sites S_2 and S_4 displayed the relatively lower values (Figure-7). The pollution indicator macroinvertebrate shows distinct pattern against stressor. Some pollution sensitive macroinvrtebrate such as Percent of EPT shows a decrease pattern whereas pollution tolerance such as percent of Chironomidae an increase pattern at downstream sites of impacted area. So as macroinvertebrate metrics indicates that, in this study a decrease in water quality from upstream to downstream[18].

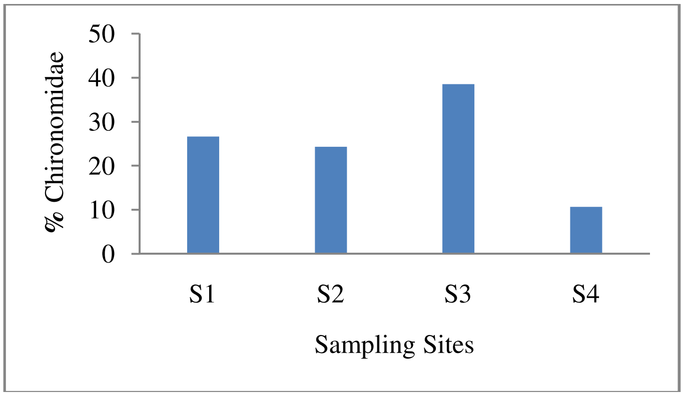

Figure-7: Percentage of Chironomidae in the reference site (S1 and other downstream sites.

Hilsenhoff Family Level Biotic Index (H-FBI): In this study the value of H-FBI index is relatively high in all sites but it is close to 10 at site 4 (Figure-8). This indicates that there is much organic pollution in this site. The status of nutrient load in stream commonly describe by Hilsenhoff Biotic Index (HBI). So, a condition of low nutrient load indicated by a low HBI value whereas huge nutrient load by high HBI scores[26].

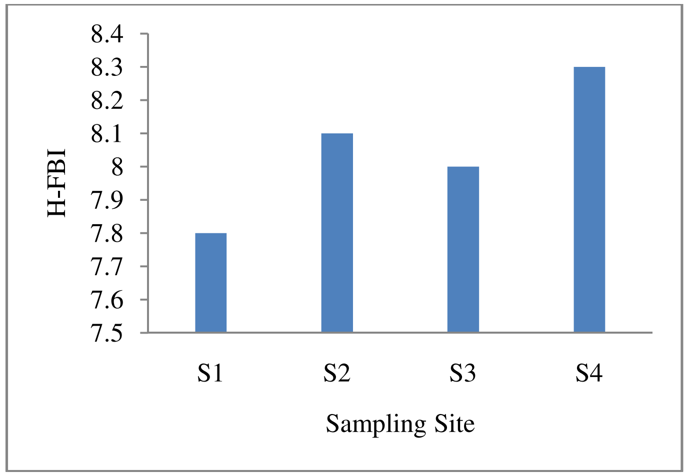

Figure-8: Hilsenhoff Family Level Biotic Index (H-FBI) in the reference (S_1) and other downstream sites.

Correlation between physicochemical characteristics and macroinvertebrate metrics: Pearson correlation (r) between physicochemical characteristics and macroinvertebrate metric at p-value (0.01 or 0.05) is indicated (Table-4). Some water quality parameters were negatively correlated with biological metrics such as Taxa richness, percent of Ephemeroptera and % EPT. Whereas other parameters of stream positively correlated metrics such as % Chironomidae, % dominant taxa, percent of CLI, the shannon diversity index and HBI index. The decline of stream quality by urbanization described with biological metrics such as Hilsenhoff biotic index[25]. According to Sarver *et al.*[27], when impairment increased, the value of taxa richness, EPT taxa, and the Shannon Index will decrease because of these metrics have a good discrimination potential for environmental stressor.

Table 4: Pearson correlation (r) between physicochemical characteristics and macroinvertebrate metrics in the study area.

Factors	Macro invertebrate taxa metrics							
	Total taxa Richness	% Ephem-Optera	% EPT	% Chiron-Omidae	CLI	FBI	% Dominant taxa	Shannon index
P^H	1.000**	-0.555	-0.447	-0.125	0.228	0.309	0.528	-0.57
	0	0.62	0.55	0.875	0.772	0.691	0.472	0.43
Temperature	1.000**	0.828	0.783	0.366	-0.887	-0.732	-0.715	0.742
	0	0.379	0.217	0.634	0.113	0.268	0.285	0.258
TDS	-1.000**	-.997*	-.977*	0.124	0.945	0.427	.982*	-0.786
	0	0.049	0.023	0.876	0.055	0.573	0.018	0.214
EC	-1.000**	-.998*	-.984*	0.029	0.925	0.502	.996**	-0.848
	0	0.043	0.016	0.971	0.075	0.498	0.004	0.152
Salinity	-1.000**	-0.992	-0.925	-0.366	.956*	0.798	0.885	-0.908
	0	0.08	0.075	0.634	0.044	0.202	0.115	0.092

**At 0. 01 significant level (2-tailed). *At 0. 05 significant level (2-tailed).

Conclusion

As the result of this study showed that, there is relatively high TDS, conductivity and salinity of water in downstream sites of the town. Macroinvertebrate assemblage generally showed a predictable pattern of change from upstream to downstream sites. The macroinvertebrate communities in the downstream sites supported fewer Ephemeroptera and none Trichoptera, but more Chironomidae and larvae of rat- tailed maggot (Syrphidae). Macroinvertebrate taxa richness, % Ephemeroptera and % EPT were reduced in downstream sites whereas % dominance taxon and % chironomidae were increased. It is likely indicates that the downstream were impacted by physical, chemical and biological changes induced by the human activities in the urban area. So in the study area the various disturbances like household trash, commercial waste, mismanagement of abattoir effluent and other anthropogenic activities are common problems that deteriorate the environment in general and the stream water quality in particular.

Acknowledgements

This research was supported by Woliata Sodo University and hence we thank Woliata Sodo University for the fund that covered to accomplish this research and we also thank department of biology where we did the lab parts of this research. Lastly we would like to thank those help us in data collection and made out map of the study area.

References

1. Booth D.B. and Bledsoe B.P. (2009). Streams and urbanization. In The water environment of cities. Springer, Boston, MA, 93-123.

2. Booth D.B. and Jackson C.R. (1997). Urbanization of aquatic systems: Degradation thresholds, stormwater detection, and the limits of mitigation 1. *JAWRA Journal of the American Water Resources Association*, 33(5), 1077-1090.

3. Cohen J.E. (2003). Human population: the next half century. *science*, 302(5648), 1172-1175.

4. Giri N. and Singh O.P. (2013). Urban growth and water quality in thimphu, Bhutan. *Journal of Urban and Environmental Engineering*, 7(1), 82-95.

5. Burres E. (1997). What Are Bioassessments? California's Surface Water Ambient Monitoring Program Clean Water Team.

6. Gahl A. (2002). Benthic Macro invertebrate and Riparian Habitat Assessment. Watershed

7. Greenway M. (2010). Wetlands and ponds for stormwater treatment in subtropical Australia: their effectiveness in enhancing biodiversity and improving water quality?. *Journal of Contemporary Water Research & Education*, 146(1), 22-38. https://doi.org/10.1111/j.1936-704X.2010.00389.x

8. Bennetti C.J., Perez-Bilbao A. and Garrido J. (2012). Macroinvertebrates as Indicators of Water Quality in Running Waters: 10 Years of Research in Rivers with Different Degrees of Anthropogenic Impacts, Ecological Water Quality-Water Treatment and Reuse. Dr. Voudouris (Ed.), ISBN: 978-953-51-0508-4. InTech editor, 95-122.

9. Water and river commission [WRC] (2001). Water facts. 2nd ed., Western Australia. ISBN: 0-7309-7564-9

10. Zinabu G.M. and Elias D. (1989). Water resources and fisheries management in the Ethiopian rift valley Lake. *SINET. An Ethiopian journal of science,* 12(2), 95-109.

11. Matusala T. (2015). Application of GIS and Remote Sensing Using Multi-Criteria Decision Making Analysis for Abattoir Site Selection: the Case of Wolaita Soddo Town, Ethiopia. Addis Ababa University. Unpublished MA Thesis.

12. Barbour M.T., Gerritsen J., Snyder B.D. and Stribling J.B. (1999). Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C. http://www.epa.gov/OWOW/monitoring/techmon.html

13. Bouchard R.W. (2004). Guid to aquatic macroinvertebrate of the upper Midwest. Water resources Center, university of Minnesota, st.paul, 208.

14. Sarda P. and Sadgir P. (2015). Assessment of Multi Parameters of Water Quality in Surface Water Bodies-A Review. *Int J Res Appl Sci Eng Technol*, 3(8), 331-336.

15. Köse E., Tokatli C. and Çiçek A. (2014). Monitoring Stream Water Quality: A Statistical Evaluation**.** *Pol. J. Environ. Stud.,* 23(5), 1637-1647.

16. Clean Water Team (CWT). (2004). Electrical conductivity/salinity. Fact Sheet, FS-3.1.3.0 (EC). https://www.waterboards.ca.gov/water_issue

17. Parsons B.G., Watmough S.A., Dillon P.J. and Somers K. M. (2010). Relationships between lake water chemistry and benthic macro invertebrates in the Athabasca Oil Sands Region, Alberta. *Journal of Limnology*, 69(1), 118-125.

18. Love N., Ellis S. and Corning B. (2007). An ecological assessment comparing three unique sites along the South Platte River.

19. Villantes Y.I. and Nuñeza O.M. (2015). Macroinvertebrates as bioindicators of water quality in Labo and Clarin rivers, Misamis Occidental, Philippines. *International Journal of Biosciences | IJB* | 6(9), 62-73.

20. Selvanayagam M. and Abril R. (2015). Water Quality Assessment of Piatua River Using Macro invertebrates in

Puyo, Pastaza, Ecuador. *American Journal of Life Sciences*, 3(3), 167-174.

21. Reif A.G. (2002). Assessment of stream quality using biological indices at selected sites in the Schuylkill River basin, Chester County, Pennsylvania, 1981-97. US Geological Survey.

22. Bauernfeind E. and Moog O. (2000). Mayflies (Insecta: Ephemeroptera) and the assessment of ecological integrity: a methodological approach. *Hydrobiologia,* 422/423: 71-83, *Acade*mic Publishers. Printed in the Netherlands.

23. Petrovic A., Milosevic D., Paunovic M., Simic S., Dordevic N., Stojkovic M. and Simic V. (2015). New data on the distribution and ecology of the mayfly larvae (Insecta: Ephemeroptera) of Serbia (central part of the Balkan Peninsula). *Turkish Journal of Zoology*, 39(2), 195-209.

24. Dacayana C., Hingco J. and Del Socorro M. (2013). Benthic Macroinvertebrate Assemblage in Bulod River, Lanao del Norte, Philippines. *J Multidisciplinary Studies,* 2(1).

25. Reif A.G. (2002). Assessment of stream quality using biological indices at selected sites in the Brandywine Creek basin, Chester County, Pennsylvania, 1981-97. U.S. Geological Survey Fact Sheet 2002–0117. https://pubs.er.usgs.gov/publication/fs11702

26. Eco Spark (2013). Water Quality Monitoring with Benthic Macro invertebrates Field Manual, Toronto.

27. Sarver R., Harlan S., Rabeni C. and Sowa S.P. (2002). Biological criteria for wadeable/perennial streams of Missouri. *Missouri Department of Natural Resources*, *Jefferson City, Missouri*.