Environemntal impact assessment of untreated waste water using benthic macroinvertebrate indicators

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Abstract— when wastewater is not treated it usually contains contaminants, and causes pollution impact on the immediate environment and the receiving water bodies. Based on this fact, this research study had taken place in the northern part of Ethiopia, to assess untreated municipal wastewater discharges impact on the nearby water bodies and the surroundings environment. In this study, waste water discharges impact on the immediate environment and the receiving water bodies estimated and solutions were suggested. Total numbers of 3,694 Macroinvertebrate individuals belonging to 47 different taxa were collected from all representative habitats selected at the three study sites. Of which 27 taxa belong to site Site1 and the rest 20 belongs to Site2 and Site3. The data were collected and subjected to statistical analysis. The types of Macroinvertebrates taken in the study could be classified as tolerant tax and sensitive tax for waste impact in the environment. In the findings, there was a significant relationship recorded between the number of macroinvertebrate or their type and their tolerance value for contaminants. The municipal wastewater Bahir Dar city, this study area, showed the pollution profile of the three study sites as very good, poor, and very poor. Furthermore when the contaminants intensity was increases the number and distribution of sensitive taxa decreases. Hence, for monitoring ecological conditions and for best characterization of this environment; regular sampling and development of a Single biological and environmental variable multimetric index are recommended.

Keywords —benthics; biomonitering; macroinvertebrate; pollutants; sensetice tax; tolerant taxa; waste water

1 INTRODUCTION

In the last five decades; because of the increased natural and man-made impacts, pollution of the human environment has been highly increased [1, 2]. Untreated wastewater discharge was one of those factors but, the issue has given less attention [14, 15]. However, since the early 1970s it has given some consideration [13, 16]. There has beena significant contamination of the human environment such as, rivers, lakes, oceans, groundwater and atmosphere by the discharge of untreated wastewater [14]. As to Metcalf, W. and Eddy, P. 2003 when untreated wastewater discharged to the water bodies it causes serious aquatic ecological system impairment. Since, untreated wastewater usually contains, nutrients mainly nitrogen and phosphorus, these compounds can affect measurably a health status of the water bodies [23, 25].

In addition, nutrients stimulate the growth of aquatic plants that can affect normal distributions of water organisms [25]. As it was proven by Wetzel and et.al, 2000, report, eutrophication of fresh water ecosystems is one of the most prevalent environmental problems responsible for water quality degradation on a world-wide scale. As a witness to this finding rivers and coastal waters exposed for eutrophication problem in many areas of the world in the recent period [14]. In few developed nations and in many developing countries, untreated wastewater is discharged to environment without any treatment or after primary treatment only [21]. For example; most of the sub-Saharan Africa is without wastewater treatment [15]. And, due to increase in human population and urbanization, an untreated waste water impact is most significant at a continent wide in causing fresh water impairment [16]. Therefore, Biological monitoring may be the most appropriate means of detecting effects on the aquatic community [39]. Regarding this more comprehensive approach of biological assessment of water quality recently introduced is the Benthic Macroinvertebrate Index (BMI) [24, 30].

The BMI is found to be an important tool for assessing the biological integrity of aquatic resources along with information on physical and chemical conditions [24]. Thus, it is importance to evaluate the impact of untreated municipal wastes on immediate environment and on the receiving water bodies using selected benthic macro invertebrates as pollution indicators [7, 16]. In this study, the impact of untreated municipal wastewater discharged to the environment and the receiving water body had been assessed. The immediate water body in this study was Blue Nile River (BNR), and the study in major investigated untreated waste water impact by using macro invertebrates as biological indicators.

1.1 Objective

The objective of this study was to assess the impacts of Municipal wastewater on the Biodiversity of immediate environment at the study area.

1.2 Importance of the study

There are many people at the downstream areas of the Blue Nile River (BNR). Those people by now whose livelihood highly dependent on the river; for domestic use, livestock, fishing and irrigations [26]. So that an assessment of pollution profile of Bahir Dar city Municipal wastewater along the storm canal is important for providing safe water for the community in the area and beyond them. Moreover, monitoring water quality and its impact on the immediate environment of the Blue Nile River is need based for all Nile basin countries. So that the findings can help to Figure out Nile River Water rehabilitation mechanisms that increase quality of the river water and sustain the environment. Also the study can give base line information to alleviate the problems of the city governments; which are necessary to plan and act over these problems at every year. Moreover, it is undeniable fact that to keep water quality; certain physical, chemical, and biological a characteristic of water has to be at standard level [16, 26].

2 MATERIAL AND METHODS

2.1 study area

Three different Stations at Blue Nile River crossing Bahir Dar City were selected in order to study the macro fauna communities. The study conducted at selected rainy seasons of the year. Thus, all the water samples were collected from study sites in the specific rainy season. Later the findings were compared with different study that had taken at water quality Control Board of Ethiopian government in the region.
From the total of six potential sampling sites identified, three sites were intensively used for the sampling of macroinvertebrates for continuous four months. Macroinvertebrates' samplings were collected from the selected three sampling sites. Technically, samplings were taken four times from each sampling station in three replicate at every thirty days for consecutive four months.

Water sampling protocol was based on the Rapid Bioassessment Protocols for use in streams and rivers [37]. The physicochemical parameters were assessed separately, however, in this paper only Macroinvertebrate data are used. For all sites there were uniform microhabitats (pools, muddy bottom and vegetated banks) i.e. the same kinds of niches were available for sampling within the 500m reach and there were no riffles and other microhabitats.

The samples were collected from all possible microhabitats are pooled into single sample for each site when the analyses were to undertake. In the field, all macro invertebrates present in the composite (pooled) sample were preserved in 70% ethanol or 10% formalin (for highly polluted sites). To maintain the consistency of sampling effort, a sample was generally obtained within one hour at each site and 20 minutes travel to the laboratory for every site, on a replication of three. Ekman samplers and Surber sampler with net were used to collect macro invertebrate in pools and bottom substrates, respectively [32]. The mesh size of the Surber sampler was 500µm with sampling area = 0.09 m^2 and the Ekman sampler covered an area of 15x15cm2. To evaluate the ' state' of macro benthic communities, the stations chosen were those adjacent to potential sources of pollution. All samples were preserved until laboratory analyses and counting. The identifications were done in the laboratory. The majority of the benthic invertebrates were identified to family level and recorded on numbers. Binocular microscope was used for identification and the keys used were those given by [38]. As to Bode et al. 1999 scores for tolerance levels were given in ranges 0-10. The standardized scores are added to produce the final multimetric score of Benthic Macroinvertebrate Index (BMI) for each sampling site (Table2.1).

2.2 Macroinvertebrates Metrics and Index Development

Metrics representing richness, composition and tolerance or intolerance measures and Shannon diversity index (SDI) were used for the Macroinvertebrate community [17, 22]. The criteria for the metrics selection were the ability to be associated with pollution level, ability to provide unique information and ability to discriminate non impacted sites from those of the impacted ones [23]. Scoring criteria are developed from examining relationships between individual metric scores and an indicator of impairment across a range of impairment levels; including undisturbed conditions. The range of numbers that might be observed for each of these characteristics is divided into 3 sub-ranges representing values expected from least stressed, intermediate stressed, and most stressed communities. Then, depending on the range into which a specific characteristic at a particular site falls, it is assigned a score. For example according to the FEPA 2005 dominant taxa greater than 35% indicates poor water quality, between 25%-35% indicates fair water quality, and less than 25% indicates good water quality. However, some unstressed habitats are also dominated by only a few taxa due to habitat, flow, and seasonal effects [39].

TABLE2.1 DESCRIPTION OF EACH MACROINVERTEBRATE METRIC AND THEIR EXPECTED RESPONSES TO INCREASING PERTURBATION [37]

BMI Metric	Description	RTI
% RT	% TIT Composition	Decrease to the down stream
Ephemeroptera (Ephem)	Mayfly in Percent	
Plecoptera (Pleco)	Stonefly in percent	
Trichoptera (Trico)	Caddis fly	
EPT	Mayfly, Stonefly and Caddis fly larvae	
Odonata (Odon)	Damson flies and dragonflies in percent	
SDI	General sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	
MEI	Abundance overall distribution, evenness and composition or richens	
Chironomid (ChiR)	Blood red midge Larvae and adults in percent	Increase to the down stream
Diptera (Dipt)	"True" fly larvae in percent	
Oligochaeta (Oligo)	Aquatic worms in percent	
Non-insect (NoIT)	Non-insects BMIs and other unidentified insects (such as Worms and Mollusks)	

KEY: Taxa Richness; (%TR), Total number of individual taxa in percent: %TIT, Response to Impairment: RTI, Shannon Diversity Index (SDI), Margalef and Evenness e^H/S index: MEI

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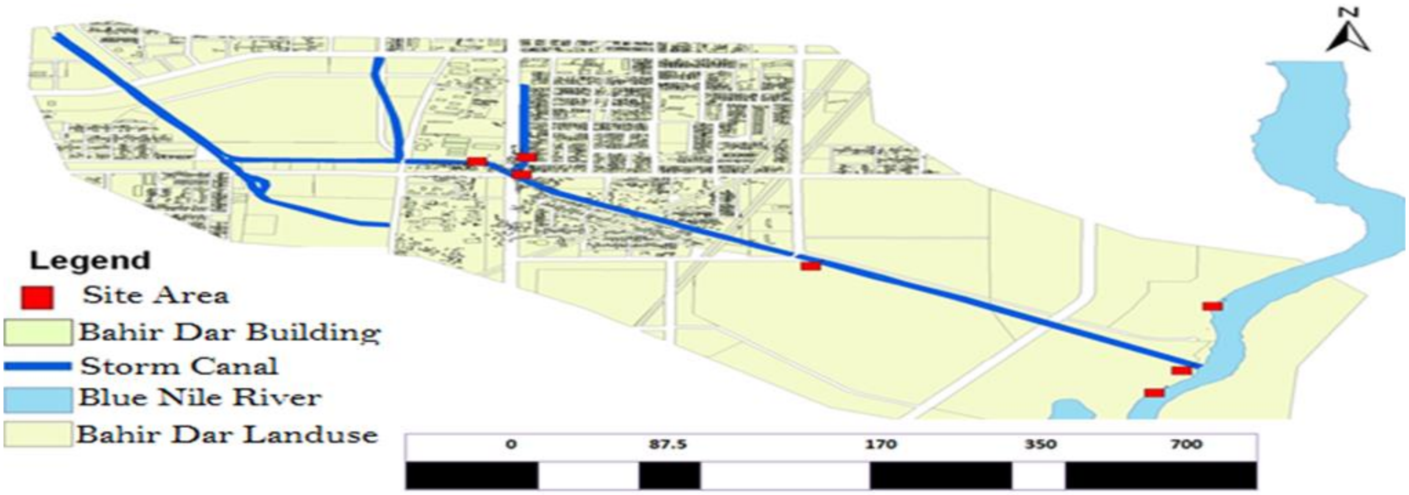

Figure 2.1., sampling site of the study area

3. RESULTS

3.1 Benthic Macro invertebrates

Twelve metrics were used in major to calculate the final Benthic Macroinvertebrate Index (BMI). During the study, total of 3,694 macro invertebrate individuals belonging to 47 different taxa were collected from the study sites (Table 2.2). All of them were identified to family level with the exception of few, such as class Hirudinea (leech). Three taxa (2 gastropods families and Hirudinea) comprised the non-insect group. One site is pointed out as a reference site. The othersites were taken as study sites. Thus, out of the 47 taxa 27 belong to the reference sites, while the downstream study sites were represented by only 20 insect families. Taxonomic groups and their abundance at each site are shown in (Table 2.2). Macro invertebrate sample sizes ranged from 1034 (S1), 813(S2), to 1847 (S3) animals per site, and taxa richness at the sites ranged from 11 at (S3), 19 at S2, to 27 at (S1). Order (Diptera, Non-Biting) was the most abundant family collected (2109 individuals). Next to (Diptera), Odonata was the common one, with a total of 854 individuals. The other rich taxa found from the study sites followed to Odonata were, Ephemeroptera (Mayflies 342 individuals), Gyrinidae (Coleoptera220 individuals), Hemiptera (Water or true bugs, 17 individuals), Plecoptera (Stoneflies 13 individuals), Mollusks, Snails, 7 individuals), Oligochaetae (Aquatic Earth worms, 4 individuals), Trichoptera (Caddisflies, 3 individuals), then Hirudinae(Leeches) and non-insects comprised in together follow (Table2.2 and 2.3).

A total number and Percentile of Macroinvertebrate at S1, S2, S3 counted for ten taxa (Table2.3). Diptera and odonata or Chironomidae among the taxa showed high number when increasing disturbance (Table2.1). The biodiversity of Bentics at all the three study sites support with their tolerance value, percentile and individual count, and richness were given below in (Table 2.2, 2.3 and 2.4) respectively.

TABLE 3.1, TOTAL NUMBER AND PERCENTILE OF MACROINVERTEBRATE AT S1, S2, S3

Taxa	Tally	S1	S 2	S 3	∑
1.Coleptra	Number	135	80	5	220
	Percent	3.6	2.1	0.1	5.9
2.Diaptrons	Number	297	219	1635	2151
	Percent	8	5.8	44.2	58.1
3.Ephimeroptera	Number	227	114	0	342
	Percent	6.1	3.1	0	9.2
4.Molscus	Number	3	4	0	7
	Percent	0.1	0.1	0	0.2
5.Oligochtae	Number	4	0	0	4
	Percent	0.1	0	0	0.1
6.Odonata	Number	316	369	169	854
	Percent	8.5	9.9	4.5	22.9
7.Trichoptra	Number	3	0	0	3
	Percent	0.1	0	0	0.1
8.Plecoptra	Number	13	0	0	13
	Percent	0.4	0	0	0.4
9.Hemiptra	Number	17	0	0	17
	Percent	0.5	0	0	0.5
10.NonInsect	Number	17	21	38	76
/Total/	Percent	0.6	0.8	1	2.4

S1= Site 1, S2=Site2, S3=Site3,

TABLE3.2, TAXA RICHNESS, EVENNESS AND SPECIES COMPOSITION ACCORDING TO MAJOR INDICES AT S1, S2 AND S3

BMI	S1	S2	S3
Taxa_S	27	11	9
Individuals	1035	812	1847
Dominance_D	0.1361	0.1435	0.6914
Shannon_H	2.423	2.316	0.7457
Evenness_e^H/S	0.434	0.6336	0.2108
Margalef	3.601	2.244	1.197

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TABLE 3.3 INDIVIDUAL COUNT OF MACRO INVERTEBRATES WITH RESPECT TO TAXA

Taxa lists	TV	S1	S2	S3	Sum
Coleoptera(Beetels)					
Dytiscidae (Predaceous Diving Beetles)	-	30	20	0	50
Elmidae (Riffle Beetles)	4	20	15	0	35
Gyrinidae (Whirligig Beetles)	-	51	15	2	68
Haliplidae(Crawling Water Beetles)	-	30	30	3	63
Water pennies	4	4	0	0	4
Diptera (Two winged or' True flies")					
Chironomidae (Blood-red)	8	16	39	28	83
Culicidae (mosquitoes)	-	0	0	7	7
Syrphidae(Rat-Tailed **Maggots,FlowerFlies)**	10	7	0	0	7
Simulidae (Black Flies larvae)	6	243	102	1528	1872
Chironomidae(pale)	6	13	54	72	139
Ceratopogonidae (Biting Midges)	6	0	0	0	0
Tabariae (Horse and deer flies)	6	10	0	0	10
Anthricdae (water snipe flies larvae)	2	8	0	0	8
Tuplidae (cranfly larvae)	3	0	24	0	24
Ephemeroptera (Mayflies)					
Baetidae (Small Minnow Mayflies)	4	155	66	0	222
Caenidae (small square –gill Mayflies	7	27	38	0	65
Leptophlebiidae (Prong-gilled Mayflies)	2	45	10	0	55
Mollusks(Snails)					
Physidae	6-8	3	0	0	3
Pulmunat (Ramshorn snail)	6-8	0	4	0	4
Oligochaetae	6-10	4	0	0	4
Odonata (Damselflies &Dragonflies)					
Coenagrionidae(Narrow-Winged Damselflies)	9	69	43	3	115
Cordulidae(Common Skimmer Dragonflies)	5	220	246	120	586
Cordulegastridae(Spke-Tail Dragonflies)	3	25	80	46	151
Aeshnidae (Darner Dragonflies)	3	2	0	0	2
Trichoptera (Caddisflies)					
Brachycentridae(Humpless Case-Maker Caddisflies	1	3	0	0	3
Plecoptera (Stoneflies)					
Perlidae (Common Stoneflies)	1	13	0	0	13
Hemiptera (Water or true bugs)					
Corixidae (waterboatmen)	-	11	0	0	11
Nepoidae(Waterscorpion)	-	6	0	0	6
Non insects (Sum up/ together)		**19**	**27**	**38**	**84**
Total		**1035**	**812**	**1847**	**3694**
Number of taxa		**27**	**11**	**9**	**47**

TV= Tolerance value (0-10), S1= Site 1, S2=Site2, S3=Site3,

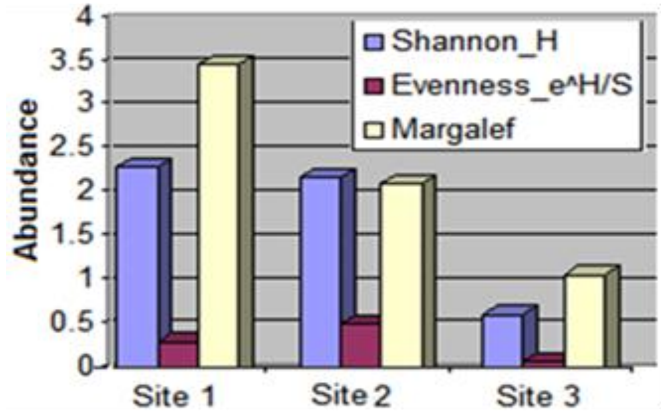

Figure 3.1, Graph of Shannon Diversity, Evenness and Richness, Index.

4. DISCUSSION

A Shannon diversity index decreased as the perturbation increased along the canal as showed in table2.4, and this was again explained in figure2.2. At S1 the value of Shannon diversity index scored was 2.43 and it was higher than S2 mean value. Shannon diversity index scored at S3 the mean value scored was the smallest (0.75) of all the others. Both the species Distribution (evenness and richness) decreased along with the perturbation (Fig2.2). This index showed significant variation downstream along pollution gradient indicating that it had been affected by pollutants and it was able to discriminate mild and severe impacts from reference condition. The distribution and evenness of the taxa was given by a graph of Shannon diversity index (Fig2.2). At S1 number of taxa of family level (27) or high but individual number (1035).When compared to the impact site (S3) which comprised a total of only 11 families but individual number of (1847) with the maximum number of individual's due to the dominant species scored at the sites. The most impacted sites (S2 and S3) registered a high value of negative indices and low value of positive indices indicating poorest habitat quality than the reference site (S1) as they can't support numerous biodiversity.

5. CONCULUSION

Benthic metric indices indicated that the reference site (S1) ranked first on all twelve metrics, while the most impacted sites (S2 and S3) ranked last on all positive metrics. A total number of taxa and %EPT (%Ephemeroptera, %Plecoptera, %Tricoptera) are all expected to decrease with increased perturbation. Diptera and Chironomidaepercent increase with increasing disturbance. The lower site (S3) obtained severely impaired scores on four metrics (EPT% Ephem, %Trico, and % Pleco) and onotherindex than the upper sites (S2) on all metrics. This findings, suggest that there was a significant relationship recorded between the number of macro invertebrate or their type and their tolerance value for contaminants. As it was proven, for impact assessment of untreated waste water on biodiversity of immediate environment and the receiving water bodies using benthic macroinvertebrate indicators is a good tool. The analytic method of evaluation was based on the recognition of ecological groups of different sen-

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sitivity to organic matter overload of municipal wastewater of the study area and their exposure to high waste discharge. In general at all the three sampled sites, macro invertebrate data indicated that the biodiversity has been affected, particularly at the upper stream the two sites were more impaired and macroinvertebrate communities were more vulnerable to wastewaters than the third site in comparisons.

Based on this it is recommended that for sustainable management of municipal wastewater, environmental protection agencies at different levels and other concerned administrative and/or nongovernmental bodies should take firm as well as technical measures. To achieve these goals the following points could be considered.

- It should be an urgent pre requisite to require Wetland construction; at discharging sites of waste water into Blue Nile River.
- The disposal of any kind of wastes should include proper design elements and meet local standards on pollutant discharge limits of effluent set by National Environmental Quality Standards of Ethiopia (FEPA, 2005).
- The infrastructure of wastewater canal in regulating the effectiveness of a constructed wetland for domestic wastewater treatment canal site-specific conditions and infrastructure of wastewater canal should be redesigned.
- As it was observed that some people use the river water for domestic purposes, drinking for cattle and for irrigation so the local communities should be aware of the pollutants to keep the river from being susceptible for chemicals and toxic substances gradually.

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7. Conflict of Interests

The author has not declared any conflict of interests

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