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EFFECT OF BAHIR DAR MUNICIPAL EFFLUENTS ON WATER QUALITY OF THE HEAD OF BLUE NILE RIVER

***ABREHET KAHSAY MEHARI,[1] SHEWIT GEBREMEDHIN,[1] AND BELAYNEH AYELE[2]**
[1]Fisheries, Wetlands and Wildlife Management Department, Bahir Dar University, P.O. Box 5501, Bahir Dar, Ethiopia
[2] Natural Resource Management Department, Bahir Dar University, P.O. Box 5501, Bahir Dar, Ethiopia

Abstract
The study was conducted with the main objective of determining the effect of Bahir Dar municipal effluents on water quality of the head of Blue Nile River. Physico-chemical parameters were measured at seven points, whereas aquatic macro invertebrates were sampled at six sites. A total of 6813 aquatic macro-invertebrate individuals belonging to 30 families were collected. The Shannon–Wiener diversity Index, the Hilsenhoff family-level biotic index, Family richness and percent dipterans were calculated and differed significantly among sampling sites ($p < 0.05$). Physico-chemical parameter mean values differed significantly among sampling sites ($p < 0.05$), dissolved oxygen mean value being higher at sampling site (A) and BOD_5, TDS and conductivity values being higher at (C5). BOD_5, conductivity and total alkalinity mean values were above permissible levels set for municipal effluents to be discharged to surface water. DO, BOD_5 and total alkalinity mean values at head of Blue Nile River were lower than WHO recommended values for drinking water. The study concludes that the Bahir Dar municipal effluents severely affected the water quality of the head of the Blue Nile River. Therefore, a municipal waste water treatment system is urgently recommended.

Key Words: *Bio-monitoring, macro invertebrates, physico-chemical parameters*

Introduction

Indiscriminate liquid waste discharge is a daily practice in many developing countries (UNDP, 2004). It is reported that 70% of industries in developing countries dispose their untreated waste into water bodies (UN-Water, 2009). In Ethiopia, almost all natural waters are polluted by municipal, industrial or commercial waste of both solid and liquid nature and hazardous material, the exact load of which is, however, not known. However, streams and rivers passing large cities such as in Addis Ababa in Ethiopia can be described as sewer lines for domestic and industrial wastes (Samuel *et al*., 2007).

Waste water disposal is a serious problem in Bahir Dar town. Major institutions and industries like Bahir Dar University, Textile factory, and Bahir Dar Abattoir discharge their effluents directly into the Blue Nile River without any treatments. Furthermore, two-thirds of all households in Bahir Dar town discharge waste water into streets and flood water drainages which ultimately discharge in to

*Corresponding Author: Abrehet Kahsay
Email: abrehetkahsay66@gmail.com

Blue Nile River (Mekonnen, 2012). Chemical and physical assessment is widely utilized to evaluate the extent of pollution of water bodies from industrial and other sources. However, the combination of biological assessment with physico-chemical assessment is the most appropriate means of detecting effects of pollution on the aquatic systems, because it can detect cumulative physical, chemical and biological impacts of adverse activities to an aquatic system (Mandaville, 2002; US EPA, 2002; Davis *et al.,* 2003).

In Ethiopia, macro invertebrate composition has been used as stream and rivers water quality indicator by different researchers (Berhe, 1988; Akalu, 2006; Sitotaw, 2006; Abay, 2007; Misganaw, 2007; Wosinie and Wondie, 2014).

However, the published information about using aquatic macro invertebrates to assess the effects of municipal wastes in Ethiopia is very rare. Therefore the objective of this study was to investigate the effect of the municipal effluents of Bahir Dar town on the water quality at the head of Blue Nile River using aquatic macro invertebrate as bio-indicators. We addressed the following specific questions: (1) what is the longitudinal gradient of pollution in the municipal canal effluents? (2) Do the observed water quality parameters exceed the maximum permissible levels of international standards? And if so, to what extent? And (3) To what extent is the water of the Blue Nile River affected by the effluents of Bahir Dar municipal.

Study Areas

Bahir Dar, the capital of Amhara National Regional State is situated on the southern shore of Lake Tana, the source of Blue Nile River, approximately 565 km northwest of Addis Ababa at an altitude of 1801 m a.s.l, latitude of 11038” N and a longitude of 37010” E. It is a rapidly expanding town with commercial centers, small industries and residences in all sectors of the town. The total population of Bahir Dar was in 2007 ca. 220,000 inhabitants and has a population growth rate of 6.6% per year (CSA, 2007), which is more than twice as high as the average population growth rate in Ethiopia.

At Bahir Dar town, there is one main effluents canal that starts from Gudo-Bahir wetlands, located at the north side of the town, and discharges its effluents made up of domestic wastewater, industrial wastewater and storm water directly in to head of Blue Nile River. The water from this river is used for different purposes like drinking, livestock watering, and irrigation by downstream communities. Besides, local people grow different vegetables and some crops at the sides of this canal using the waste water.

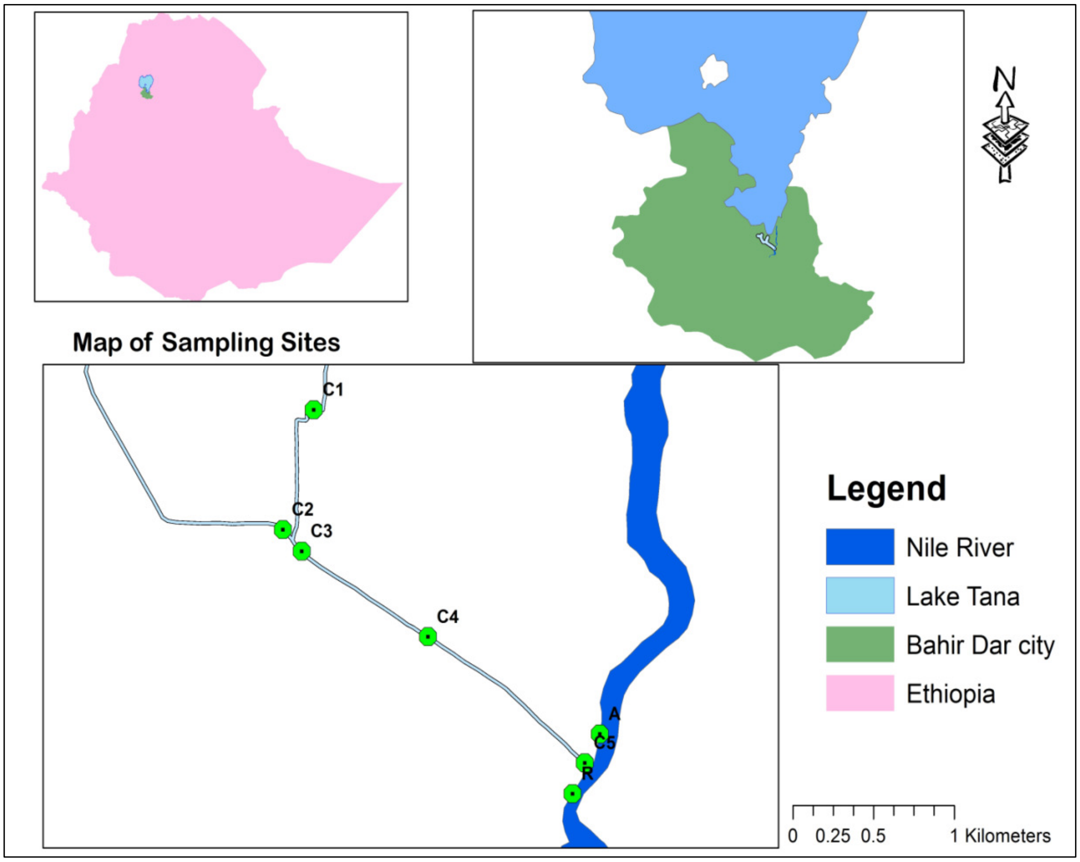
Materials and Methods

Sampling

A total of seven sampling sites: five sites from main municipal canal and two from Blue Nile River (one site upstream to effluents joining point to head of Blue Nile River and one the most downstream site , after the effluents joined to head of Blue Nile River) were selected (Klemm *et al.,* 1990). The sampling sites were designated as C1 to C5 for main municipal canal, A for upstream and R for downstream sites from River (Table 1 and Fig 1). Samples were collected in August and December, 2013 and April of 2014.Two replications per site with two dipping effort was applied.

Table 1: Description of sampling sites

Sampling Site name	Coordinates	Altitude (m a.s.l)	Descriptions
A	11^{0} 34` 42.38’’ N $37^{0}$24`34.80``E	1789	Head of Blue Nile River. Most upstream site, located above the point where the main canal effluents join the river. Covered with a mixed vegetation of macrophytes, shrubs and large trees.
C1	11^{0}35`13.85``N $37^{0}$23`22.65`` E	1798	Canal with asphalt bottom. Most northern located canal site, no vegetation coverage.
C2	11^{0}34`52.95``N $37^{0}$23`07.56``E	1798	Canal with mud bottom. Second most northern canal site. Few dominant types of vegetations. Local people grow different types of vegetables.
C3	11^{0}34`49.14``N 370223`17.72`` E	1797	Canal with mud bottom. Local people grow different types of vegetables
C4	11^{0}34`31.38``N $37^{0}$23`45.18``E	1796	Canal with mud bottom. Most southern canal site, at the main gate of Bahir Dar University, Papyrus Cyprus vegetation planted.
C5	11^{0}34`09.95``N $37^{0}$24`14.56``E	1797	This site located where the water of the main municipal canal enters the river. Local people grow vegetables
R	11^{0}34`03.99``N $37^{0}$24`16.778``E	1798	Head of Blue Nile river, most downstream site



Data collection

Physico-chemical Parameters

Water temperature, dissolved oxygen (DO), pH, total dissolved solids (TDS) and conductivity were measured *in situ* using YSI 556 MPS Multi-probe field meter. Water samples for laboratory analysis were collected and stored in polythene bottles that had been pre-washed with 10% nitric acid and thoroughly rinsed with de-ionized water (Jain and Bhatia, 1987). Samples for BOD_5 were analyzed according to standard methods (APHA, 1998) at the laboratory of the Institute of Technology of Bahir Dar University. Total hardiness, total alkalinity and phosphate were analyzed at Amhara Design and Supervision work Enterprise laboratory using Paqualab 700 photometer.

Aquatic Macro invertebrate Data

Aquatic macro-invertebrates were sampled using a D-frame net with mesh size of 500 µm. Next they were removed with forceps from the net and put into bottles. All samples were preserved with 70% ethanol until laboratory analysis and counting. All the organisms in the sample were enumerated and identified to the family level using a dissecting microscope and standard keys (Edmondson, 1959; Jessup *et al.,* 1999; Gooderham and Tysrlin, 2002 and Bouchard, 2004).

Data Analysis

Descriptive statistics were used to analyze water quality data. For the aquatic macro-invertebrate communities four different indices were calculated for each sampling sites. The Shannon-Wiener Diversity Index (H') is a diversity index that incorporates richness and evenness. A high H′ indicates a good water quality. H' was calculated as follows:

$H' = - \sum (P_i \ln [P_i])$ ………………Eqn (1)

Where: P_i is the relative abundance (n_i/N) of family i, n_i = number of individuals in family i and N = total number of individuals in all families. H′ is ranging from 0 for a community with a single family, to over 7 for a very diverse community.

The Hilsenhoff Family-level Biotic Index (HFBI) is a biotic index that is calculated by multiplying the number of individuals of each family by an assigned tolerance value for that family. Assigned tolerance values ranged from 0 to 10 for families and increase as water quality decreases (Hilsenhoff 1988; Bode *et al*., 1996). High HFBI community values are an indication of organic pollution, while low values indicate good water quality. This index was calculated as follows:

$HFBI = \Sigma [(TV_i)\ (n_i)] / N$ ………Eqn (2)

Where: TV_i is tolerance value for family i, n_i is the number of individuals in family i and N is the total number of individual in the sample collection.

The percentage of Dipterans tends to increase with a decrease in water quality; they become increasingly dominant in terms of percent taxonomic composition and relative abundance along a gradient of increasing pollution (Ferrington, 1987; Plafkin *et al*., 1989). This index was calculated as follows:

% Dipterans = 100 * (# Individual Dipterans / Total Individuals in sample)………Eqn(3)

Family richness reflects the health of the community as a measurement of the variety of families present. Richness increases with increasing water quality, habitat diversity, and habitat suitability. This index was calculated as follows:

FR = # the number of different family) of animals in the sample…………….Eqn (4)

Excel spreadsheets and statistical software (SPSS version 20) were used for the statistical analysis. One way ANOVA was used to evaluate differences in water quality data and aquatic macro invertebrate metrics among the sampling sites. Differences among means were tested using Tukey HSD.

Results and Discussion

Physico-chemical Parameters

The mean values of dissolved oxygen that ranged from 2.4 mg/l at sampling site C5 to 7.5 mg/l at sampling site A showed significant variation among sampling sites (F=12.354, P=0.000, Table 1). A higher mean value of DO was recorded at sampling site of C4 than other canal sites could be due to the presence of dense Papyrus Cyprus and other plants at this site. The drastic decrease of dissolved oxygen mean values at sampling site C5 may be attributed to the added high organic pollutants from main campus of Bahir Dar University (Peda campus) students and staff cafeterias` and toilets`. Study conducted by Prabu *et al*. (2008) also showed low dissolved oxygen value with mean value of 3.2 mg/l in sewage wastewater that discharges to Huluka River from Ambo town in Ethiopia.

The mean values of BOD_5 ranged from 15.3 mg/l at sampling site A to 39.3 mg/l C5 .The mean value showed significant variation among sampling sites (F= 40.346, P=0.000), the value at C5 being higher than at the other sites (Table 2).The high levels of BOD_5 are the indicators of the toxic waste strength of the effluents (Yusuff and Sonibare, 2004; Geetha *et al.,* 2008).

The pH mean values were 6.3 for C2 and 7.67 for A. The mean values did not differ significantly among sampling sites (F=1.421, P=0.274) (Table 2). The temperature mean values ranged from 17 ^{0}C at C2 to 24.27 ^{0}C at R and values differ significantly among sampling sites (F=5.744, P=0.003) (Table 2). The pH of sewage wastewater of Ambo town was 7.9

and temperature was 15.2 ^{0}C (Prabu *et al.,* 2008).

The mean values of TDS varied from 101.7 ppm at sampling site A to 738.3 ppm at C5, mean value showed significant variation (F=25.268, P=0.000), the value at C5 being significantly higher than at other sites (Table 2). Study conducted at urban waste water of Addis Ababa showed mean value of TDS 328 ppm (Dagne , 2010) which is much lower than the TDS values found in the present study.

The mean values of conductivity ranged from141 µS/cm at sampling site A to 1470 µS/cm for C5. There was significant variation among sampling sites (F=51.953, P=0.000); the value at C5 being significantly higher than other sites (Table 2).

The mean value of sulphate ranged from 7mg/l at sampling site A to 25.7mg/l at sampling site C5. The mean value did not show significant variation among sampling sites (Table 2). The mean values for phosphate ranged from 0.2 mg/l at sampling site (A and R) to 2.6 mg/l at sampling site C5 and values did not significantly varied among sampling sites (Table 2).

Table 2: Mean (± SE) values of water quality parameters of study sites

Parameters	C1	C2	C3	C4	C5	R	A	P-value
DO (mg/l)	4.9±1	4.8± 0.4	4.8± 0.4	6.8± 0.4	2.4± 0.3	7.21±1	7.5±0.4	.000
BOD_5 (mg/l)	34.7± 4	37.0± 4	28.3± 0.6	19.0± 0.6	39.3± 0.3	18.17±1.9	15.3± 0.4	.000
pH	7.6± 0.9	6.3± 0.1	6.5± 0.5	6.8± 0.5	6.8± 0.2	7.67±0.4	7.3±0.2	.274
Temperature(°C)	21.2± 1	17.0± 0.6	21.7± 1.2	18.6± 0.8	20.7± 1.7	24.27±0.4	23.6± 1.3	.003
TDS (ppm)	667± 68.2	656.7± 35.9	505.3± 43.6	473.3± 97.6	738.3± 27.1	129±14.8	101.7± 9.7	.000
Conductivity(µS/cm)	907.7± 42.2	968.3± 15.9	975.7± 12.6	858.7± 20.5	1470± 162.7	168±8.1	141± 36.1	.000
Total Alkalinity(mg/l)	218±24	215±27.5	225±13	208±13.2	227±20.3	95±4.3	84±3.5	.000
Total Hardness(mg/l)	295±10.4	238±21.3	221±13.6	187±17.4	313±17.6	110±15.5	91±3.7	0.28
So_4^{2-}(mg/l)	18.7±1.4	17±1.3	14.8±1.4	18.7±	25.7±1.1	9±.6	7±.00	.911
$Po4^{3--}$(mg/l)	2.2±.6	1.6±.6	1±.2	1.6±.9	2.6±1.8	0.2±.00	0.2±.00	.095

As shown in Table 3, mean Value of BOD_5 was above maximum allowable limits set by international finance corporation (IFC) Environmental, health, and safety guidelines and the standards for industrial and municipal wastewater discharges to surface water by Saudi Arabia adopted by the Presidency of Metrology and Environment (PME).

The mean value of conductivity was above maximum allowable limits set by South Africa standards. Moreover, mean value of phosphate was above maximum allowable limit set by Kingdom of Saudi Arabia standards for industrial and municipal wastewater discharges to surface water.

Discharging the effluents containing high BOD_5, conductivity and phosphate in to receiving surface water may result in physiologically stressful conditions for sensitive aquatic organisms but, can create favorable condition for tolerant disease-causing organisms.

Generally, the increment of pollutants going down through the open canal could be due to the inappropriate disposal of wastes from households, commercial centre's, public centers, garage and petrol stations and some parameters clearly showed that the waste water can have effects both on aquatic life and human around the study area.

Table 3: Characteristic of Bahir Dar municipal canal effluents joining the Head of Blue Nile River compared to guideline values of IFC (2007), KSA (2012) and SA (DWA) (2008)

Parameter	Minimum	Maximum	Mean	IFC	KSA	SA(DWA)
DO (mg/l)	3	7	5	-	-	-
BOD_5 (mg/l)	17	42	31	30	10	-
pH(pH Units)	5.87	8.70	6.81	6-9	6.5-8.5	5.5-7.5
Temperature (^{0}C)	16	24	19.8	-	-	-
TDS (ppm)	316	796	608	-	-	-
Conductivity (µS/cm)	823	1671	1036.1	-	-	150
Total Alkalinity(mg/l)	180	269.80	218.5	-	-	-
Total Hardiness(mg/l)	75	410	250.8	-	-	-
So_4^{2-}(mg/l)	.52	47	18.9	-	600	-
Po_4^{3--}(mg/l)	.20	4.50	1.8	-	1	2.5

Even though, it was evident that local people grew vegetables and crops at sides of the canal using the waste water, mean values of BOD_5 , conductivity and total alkalinity indicates the wastewater from Bahir Dar municipal (C1, C2, C3, C4 and C5) are unfit for irrigation purposes. Moreover, people were using water from the River for drinking, bathing and livestock watering , mean values of DO, BOD_5 and total alkalinity from head of Blue Nile River (A and R) were lower than the WHO recommended values for drinking purpose (Table 4).

Table 4: Comparison of Mean values of municipal canal waste water with FAO (1995) standards water for irrigation and River water with WHO (2008) standards water for drinking purposes

Parameter	C1	C2	C3	C4	C5	FAO	R	A	WHO
DO	4.9	4.8	4.8	6.8	2.4	2	7.21	7.5	>10
BOD_5	34.7	37.0	28.3	18.0	39.3	10	18.17	15.3	≤10
pH	7.6	6.3	6.5	6.8	6.8	6.5-8.5	7.67	7.3	6.5-9.2
Temperature	21.2	17.0	21.7	18.6	20.7	25	24.27	23.6	30
TDS	667	656.7	505.3	473.3	738.3	2000	129	101.7	300
Conductivity	907.7	968.3	975.7	858.7	1470	350	168	141	250
Total Alka.	218	215	225	208	227	200	95	84	<75
Total Hard.	295	238	221	187	313	350	110	91	<100
SO_4^{2-}	18.7	17	14.8	18.7	25.7	20	9	7	20
PO_4^{3-}	2.2	1.6	1	1.6	2.6	3	0.2	0.2	_

Aquatic Macro Invertebrate Taxa

A total of 30 families comprising 6813 individuals were collected from the six sites (C2, C3, C4, C5, A and R) during the study period. As shown in Table 5, the total number of family present at each site ranged from 11 (C2) to 16 (A), while the total number of individuals present at each site ranged from 229 (R) to 4916 (C5). The major components of the community were Clucidae (4146), Chironomidae (594), Ephydiridae (444), Syrphridae (437), and Belestomatidae (202). The families least encountered were Dytiscidae (2) and Sciomonzydae (5). The aquatic macro invertebrate communities were dominated by the tolerant taxa dipterans; together they represented more than 84% of the observed individuals. The tolerant Culicidae (Dipterans) were the most dominant family. Sensitive taxa as Ephemeroptera, and Trichoptera represented together only 1.2% of the observed numbers, whereas Plecoptera were totally lacking. The opportunistic pollution tolerant aquatic macro invertebrate taxa recorded at these stations are known to thrive in organically polluted areas of aquatic environments. Furthermore, the total number of families (30) observed in the present study was comparable with Wosinie and Wondie (2014) but was rather low compared with other studies in Ethiopia (Mehari *et al.,* 2014; Sitotaw, 2006) and in Africa (Kibichii *et al.,* 2007; Kasangaki *et al.,* 2008; Masese *et al.,* 2009).

Table 5: Number of aquatic macro invertebrates collected from the study sites

Family/order		Sampling sites							
	TV	C1	C2	C3	C4	C5	A	R	Total
Acarina		NA							
Tetragnathidae	4	NA	0	0	0	0	12	0	12
Dipterans									
Ceratopogonidae	6	NA	0	0	13	7	24	0	44
Chironomidae	8	NA	160	67	40	309	13	5	594
Culicidae	8	NA	49	141	51	3845	23	37	4146
Ephydiridae	5	NA	37	0	31	374	0	2	444
Psychodidae	6	NA	5	3	6	55	0	0	69
Sciomonzydae	10	NA	0	0	0	5	0	0	5
Syrphridae	8	NA	58	32	64	283	0	0	437
Tabanidae	8	NA	0	5	0	6	0	0	11
Coleopteran									
Dytiscidae	5	NA	0	0	0	0	2	0	2
Elmidae	5	NA	0	0	15	0	16	1	32
Halpilidae	5	NA	0	0	20	0	0	0	20
Hydrophilidae	5	NA	0	0	0	0	0	13	13
Hemiptera									
Belestomatidae	9	NA	60	13	17	9	49	54	202
Corixidae	8	NA	0	13	10	0	0	0	23
Gerridae	9	NA	0	27	0	0	0	13	40
Naucoridae	6	NA	0	16	23	5	10	0	54
Nepidae	7	NA	0	0	0	0	0	7	7
Notonectidae	9	NA	0	0	0	3	20	0	23
Veliidae	7	NA	23	0	7	0	94	0	124
Snails									
Hydrobiidae	8	NA	4	15	5	0	0	0	24
Physidae	7	NA	13	20	0	9	24	12	78
Planorbidae	7	NA	0	19	0	0	0	0	19
Odonata (Damsel and Dragon)									
Aeshnidae	3	NA	0	0	0	0	30	12	42
Coenagriondae	9	NA	12	30	25	3	29	58	157
Gomphidae	9	NA	0	0	0	0	13	5	18
Libellulidae	9	NA	48	38	4	0	0	0	90
Ephemeroptera									
Baetidae	5	NA	0	0	0	3	12	9	24
Caenidae	6	NA	0	0	0	0	18	1	19
Trichoptera									
Hydropsychidae	4	NA	0	0	0	0	40	0	40
Total individual			469	439	331	4916	429	229	6813
Total family			11	14	15	14	16	14	30

NA: not available

Aquatic Macro invertebrate Community Structure

The mean value of H' ranged from 0.78 at C5 indicating that it has been affected by pollutants to 2.3 at A having better diversity. The H' value showed significant variation among sampling sites (F = 17.482, P = 0.000); the value being significantly higher at A than other sampling sites (Table 6). The H' value of less than 1 indicates highly polluted, 1–3 moderately polluted, and greater than 4 unpolluted water bodies (Wilhm and Dorris, 1968). In present study, sampling sites C2, C3, C4, R and A signify moderate pollution whereas, C5 indicates high pollution conditions.

The mean values for HFBI ranged from 8.11 at sampling site C3 to 6.67 at sampling site A. Differences among sampling sites were significant (F = 22.562, P = 0.000). The Hilsenhoff Family level biotic index was developed to detect organic pollution. In this study, all sites showed highest HFBI values; suggesting fairly poor (A and C4) and poor (C2, C3, C5 and R) water quality conditions (Hilsenhoff, 1988).

Family richness ranged from 16 at sampling site A to 11 at sampling sites C2 (Table 6), differences among sampling sites were significant (F = 5.907, P = 0.006). Based on Plafkin (1989) criteria for Family richness, all sampling sites were moderately impacted and this might be due to the elimination of the sensitive taxa due to pollution.

The mean value for percent dipterans were high at sampling site C5 and values significantly varied among sampling sites (F= 4.94, P=.000) (Table 6). Since most dipterans larvae contain hemoglobin they are able to survive low oxygen conditions (Lake, 2003) and their higher abundance is indication of poor water quality (Masese *et al.,* 2013).

Table 6: Mean values for Shannon wiener diversity index (H') , Hilsenhoff Family biotic index (HFBI) , Taxa richness (TR) and percents dipterans (% dipterans)

	C1	C2	C3	C4	C5	R	A	P-value
H'	NA	1.53	1.27	1.9	0.78	1.96	2.3	.000
HFBI	NA	7.9	8.11	7.44	7.76	7.88	6.67	.000
TR	NA	11	14	15	14	14	16	.006
% Dipterans	NA	66	56	63	98	20	14	.000

Conclusion

Most water quality parameters of effluents were above acceptable levels set by international standards for effluents to be discharged to surface water and FAO maximum permissible level set for waste water to be used for irrigation purposes. Besides, some water quality parameters of the head of Blue Nile River were above WHO maximum permissible level set for drinking purposes. In addition, aquatic macro invertebrate's indexes showed deteriorated water quality conditions.

Therefore, to reverse the adverse outcomes of effluents, the Town Service Administration Office Authorities of Bahir Dar Town should develop municipal waste treatment plant or other mechanisms for treating wastes and minimizing their adverse effect on environment. Furthermore, Bahir Dar University which is one of the big public institutions in the country should develop institutional wastewater treatment plants and management systems that can be a model for other institutions in Bahir Dar town.

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