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Research Article

Bacteriological and Physicochemical Profile of Water Samples Collected from River and Stream Water Basins Crossing Gondar town, North West Ethiopia

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Abstract

Bacteriological and physicochemical properties of water samples collected from river and stream crossing the Gondar town was investigated. A total of 60 samples were taken and studied for three consecutive months. Physicochemical properties such as turbidity, electrical conductivity, pH, total hardness, nitrite, chloride, calcium, phosphate, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and sulfate were estimated. The pH, EC, total hardness, Mg, sulfate, and chloride level in all the 20 sampling areas were below the recommended national and international guideline values, whereas phosphate, BOD, COD and turbidity showed maximum variation. At sampling areas 6 and 19, high and low value of nitrate was recorded respectively. At sample areas of 4, 8, 9, 10 and 11, calcium level was high. The coliform MPN test results in all 20 sampling areas were more than DEDWQS (Draft Ethiopian drinking water quality system) and WHO surface water bacterial concentration guideline (0-10 coliform/100 mL) recommendation. Based on the biochemical tests, presence of *Enterobacter aerogenes, Klebsiella pneumoniae, Proteus vulgaris, Pseudomonas aeruginosa, Salmonella* and *E. coli* were confirmed from 20 sampling areas. There were a statistically significant ($p<0.05$) difference among 20 sampling areas with respect to TCF MPN/100 mL and FCF MPN/100 mL of bacterial enumeration. There were also strong positive correlation between physicochemical and bacteriological parameters ($p<0.01$) and their "r" values found between $-1<0<1$. The result of the study showed that river and stream water basins that cross Gondar town were severely polluted. Therefore, suitable waste disposal treatment strategies as well as risk management and interim solution are needed to prevent adverse environmental and health impact.

Keywords: Bacteriological, Gondar town, colony forming unit, physicochemical, waste disposal.

Introduction

In Ethiopia, the ever increasing human population, uncontrolled urbanization and inadequate sanitation infrastructure cause serious quality degradation of surface water. Human and animal pathogens are the main important contaminants of the environment with transmission through the soil, agriculture, water and sediment (Bonetta *et al*., 2011; Pall *et al*., 2013). Surface water pollution in the water shed is seemingly a result of raw water discharge and the low dilution capacity of the river during the dry period (Amare, 2005). Most water pollutants in towns are carried by large and small waste water drainage canals, streams and industrial influents, household wastes flows down to the main rivers which crosses the town, which is one of the major problems in cites (Loague and Corwin, 2006; Wassie, 2008). Water quality refers to the characteristics of a water supply that will influence its suitability for specific use i.e., how well the quality meets the needs of the user which can be defined by certain physical, chemical and biological characteristics (FAO, 1998; Onyango *et al*., 2018).

Water quality of rivers is best in the head (upstream) of river and stream water basins where rainfall is frequent, while it declines as rivers flown through region where land use and water use are high due to intensive agriculture, large towns industry and a recreation areas increases (APHA, 1995; Amare, 2005; Jung *et al*., 2014). Similarly the uncontrolled and excessive use of fertilizers and pesticides has long term effects on ground and surface water resources (Loague and Corwin, 2006; Pall *et al*., 2013). Water quality alteration constitutes major environmental impact of many water use development activities and the most obvious source of quality alteration is due to the discharge of municipal and industrial waste and addition of toxic substance to natural water (WHO, 2006). More challenging is the unsafe disposal of these wastes in to the ambient environment (water bodies) especially; rivers and streams through waste water drainage lines of the towns that has been rendered the natural water resources unsuitable for both primary and/or secondary usage (Siyum, 2005; Ouattara *et al*., 2011).

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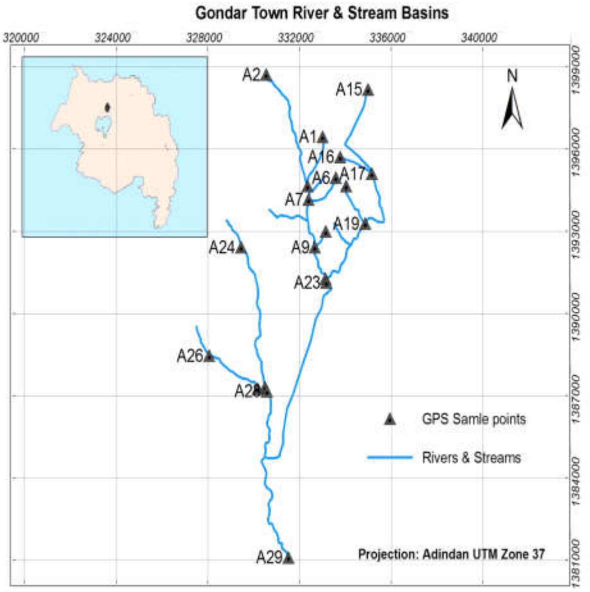
Fig. 1. Map of Gondar City River and stream distribution.



Source: ETHIO_GIS

Note: A1=Up stream of stream fechifachit, A2=Up steam of River Keha, A3=Joint of river Keha and stream Fechifachit, A4= Up stream of steam Bisnit, A5= Joint of river keha and stream Bisnit, A6=Up stream of stream Kidame Gebeya, A7=Joint of river Keha and stream Kedame Gebeya, A8=Effluent of river Keha, A9=Effluent of river Angereb, A10=Joint of river Angereb and river Keha, A11=Up stream of stream Enkodo, A12= Down steam of stream Enkodo, A13=Up stream of river Angereb, A14=Up stream of river Dimaza, A15=Up stream of River Shinta, A16=Effluent of river Dimaza, A17=Effluent of river Shinta, A18=Joint of river Shinta and Dimaza, A19=Joint of river Megech and DIMAZA, A20= Down steam of river Megech.

Many African countries, including Ethiopia faced a comprehensive biological contamination of rivers and streams, which needs a suitable waste disposal and treatment strategies as well as risk management and interim solution to prevent adverse environmental and health impact from waste water. In many parts of Ethiopia, waste water are disposed to wells, ponds, streams, rivers and treatment plants which is used as a source of irrigation as well as for drinking (Yohannes and Elias, 2017). Similarly, water supply and sanitation is inadequate and most of the populations in urban and rural areas do not have access to safe adequate water supplies and sanitation facilities (Alemayahu *et al.,* 2001; Kolarevic *et al.,* 2011). Regarding food, water and personal hygiene, only few households show sufficient understanding of environmental sanitation or hygiene practices, as a result, three-fourths of the health problems in Ethiopia are due to communicable diseases attribute to unsafe/inadequate water supply and unhygienic/ unsanitary waste management, particularly excreta (NWWR, 2004).

Nowadays, Gondar town faces severe water pollution in rivers because of fast urbanization, industrialization and a rapid growth of population, and overcrowded living style of the people, as well as unsafe disposal of industrial, community and municipal wastes that flows down the river and stream water basins causes severe health problem of the people those who use these rivers and streams water for drinking, washing and irrigation. Hence, to take appropriate control measures, the present was initiated to know the status of bacteriological and physicochemical conditions water samples collected from river and stream water basins crossing Gondar town.

Materials and methods

Description of the study area: Gondar city is located 748 km North West of Addis Ababa which is the capital city of Ethiopia. It stands at an elevation of 2260 meter above sea level and is bounded by 12°35′ 07″ North and 37° 20′ 08″ East longitudes. The city has many natural resources, such as 4 main rivers and 33 main stream basins, which are crossing the town. These rivers and streams are used for washing, small agricultural irrigation activities and serve as natural sewerage line for community, industrial, municipal drainage channel and community over flood (run off) wastes.

Sampling design and experimental study: The experimental design used was cross-sectional laboratory based experiments to compare and analyze the bacteriological and physicochemical parameters. In this study, 20 major sampling areas were marked in the river and stream basins which cross the Gondar town. In each sampling area, 3 samples were collected and totally 60 samples were collected, analyzed and compared with WHO and DEDWQS recommended guide line values.

Sampling point location and selection: Twenty major sampling areas of 4 main rivers and 6 streams that cross Gondar city was identified to represent the downstream water quality variation, based on the rate of the severity of water pollution. Twenty major sampling areas were selected based on the rate of human interference, industrial and agricultural activities, municipal wastes which have been taking place from upstream to the downstream of river and stream water basins. Sampling points were selected by field observation and GPS satellite data was collected to allocate exact sampling location (Fig. 1).

Water sample collection: One hundred fifty milliliter water samples were collected at each sampling points by direct immersion of bottles on water sample points handled by rope. Water sample collection was carried out during summer seasons hence flooding might affect the spatial and temporal variation of water quality.

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Grab water sampling method was employed during collection i.e., a single volume of water taken all at one time from a single point. Bottles were preserved using icebox, after sample collection, a total of 60 water samples were taken to the Applied Microbiology laboratory, University of Gondar, NGSWRI (North Gondar Soil and Water Research Institution) and GTDWSSS (Gondar Town Drinking Water Supply and Sewerage Service) laboratory for subsequent analysis. The study was conducted in three consecutive months from August 2017 to October 2017.

Physicochemical parameter analysis: The physiochemical water quality analysis was measured by using digital electronic instruments. Turbidity of water samples was measured by using digital turbid metric 2100n instrument; EC and pH was measured by using U10 water checker instrument. Cationic and anionic chemical analysis was employed different procedures and analytical methods. Nitrate, Phosphate, Calcium, Magnesium, Sulfate and Chloride was measured by using 7100 photometer with the recommended reagent. BOD and COD were measured by using digital electronic HANNA BOD meter and COD meter.

Bacteriological quality analysis: Sixty water samples have been prepared by adding10mL of sample water into the three double strength lactose broth/LTB/tubes and 1 mL of water sample into the three single strength lactose/LTB/ tubes and 0.1 mL of water sample to the three single strength lactose/LTB/tubes. The MPN (Most Probable Number)/100mL of coliform organism in the water sample was estimated by counting the number of tubes positive for acid/gas production in each of the three categories comparing with that of MPN index table, multiplied by a factor equal to the denominator of the highest dilution that gave positive results in all three tubes. Enumeration, isolation and identification of bacterial genera were done using spread and streak plate isolation techniques on selective and differential media.

Total and fecal coliform count: Total coliform (TCF) bacterial examination was standardized into three tests, which indicates the general hygienic quality of water. The first presumptive test was a screening test by which 10 mL of sample water was added into the three triple strength lactose/LTB/BGLB/ tubes and 1 mL of water sample was added into the three single strength lactose/LTB/BGLB/ tubes and 0.1mL of water sample was added to the three single strength lactose/LTB/BGLB/ tubes and incubated at 37°C for 24 h. After incubation any sample in the presumptive test that showed 10% gas/acid production or turbid growth was considered unsafe, and the second screening confirmation test was performed on tubes displaying positive reaction which indicates recent fecal pollution of water a risk for infectious diseases.

The third test was done on BGLB medium for the differentiation of coliform (producing a green metallic sheen) from non-coli form colonies. The estimation of coliform was in the form of a "most probable number (MPN) index. Finally by measuring/computing the number of total and fecal coliform bacterial concentration significance mean difference ($P<0.05$) was calculated and a judgment has been made to the river and stream water usability (APHA, 1991).

Isolation and Identification of microorganisms: Bacterial genera were isolated by using EMB/BGLB. For biochemical test, selective and differential media was used (Eosn Methyl blue, Nutrient agar and broth, MRVP broth, Simmon's Citrate Agar and tryptophan broth). Each bacterium isolate were inoculated on plate count agar (PCA) incubated at 37°C for 24-48 h to enumerate the CFU.

Data analysis: The average data of TCF and FCF, MPN/100 mL bacterial concentration of 20 major sample areas were subjected to the analysis using SPSS.V.20. Two way ANOVA was used to analyze the distribution of the coliform indicator organisms in each major sample areas. The average data of physical and chemical parameters were analyzed compared with respect to the WHO and DEDWQS surface water guide line values. Finally the impact of bacteriological contamination and physiochemical parameter analysis of each sample areas were analyzed based on spearman's correlation (APHA, 1995).

Results

Bacteriological test results: The value of total coliform count was ranged from 115 MPN/100 mL to 958 MPN/100 mL. The highest TCF was recorded at sample area 4 and the lowest TCF was recorded at sample area 2. The value of fecal coli form count was ranged from 42 MPN/100 mL to 469 MPN/100 mL. The highest FCF was recorded at sample area 4 and the lowest FCF was recorded at sample area 20 (Table 1). The multiple comparison statistical analysis results showed that FCF and TCF MPN/100 mL bacterial concentration counts were significantly different in 12 sample areas and in 4, sample areas respectively down the column of each sample areas at $P<0.05$ (Table 2). In the biochemical test, six bacteriological genera *Escherichia coli, Enterobacter aerogenes, Klebsiella pneumoniae, Proteus vulgaris, Pseudomonas aeroginosa* and *Salmonella* were isolated. Relatively high CFU of the above mentioned bacterial species were recorded at sample areas 3, 4, 5, 6, 7, 11 and 12 while low CFU were recorded at sample areas 1, 2, 8, 9, 10, 13, 14, 15, 16, 17, 18, 19 and 20. *Proteus vulgaris* was not observed at sample areas 1, 2, 9, 16, 17, 18, 19 and 20. Similarly at sample areas 1, 2, 9, 10, 16, 17, 18, 19 and 20 *Salmonella* was not recorded (Table 3).

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Table 1. The mean bacterial concentration in 20 sample areas.

Sample areas	TCF MPN/100 mL	FCF MPN/100 mL
A1	256±0.593	50± 0.876
A2	115± 0.105	69± 0.175
A3	797± 0.106	262± 0.182
A4	958± 0.070	469± 0.596
A5	887±0.193	346± 0.456
A6	732± 0.105	310± 0.175
A7	627± 0.245	281± 0.438
A8	480 ± 0.140	235± 0.316
A9	460 ± 0.410	259± 0.053
A10	497± 0.531	251± 0.035
A11	593± 0.315	141± 0.315
A13	265± 0.876	133± 0.298
A14	299± 0.455	240± 0.561
A15	373± 0.736	110± 0.436
A16	375± 0.578	227± 0.473
A17	411± 0.613	259± 0.753
A18	366± 0.769	240± 0.333
A19	258± 0.720	66± 0.719
A20	199± 0.718	42± 0.561
WHO DEDWQS	0—10 MNP/100 mL 0—10 MNP/100 mL	0—10 MNP/100 mL 0—10 MNP/100 mL

Table 2. TCF and FCF MPN/100 mL bacterial concentration multiple comparison.

Sample areas	TCF (MPN/100 mL)	"P" value	FCF (MPN/100 mL)	"P" value
A1	121.13±178.94	0.39	158.52±120.44	0.30
A2	342.67±178.94	0.12	163.11±120.44	0.29
A3	237.91±178.94	0.01	124.34±120.44	0.04
A4	205.51±178.94	0.03	93±120.44	0.07
A5	238.24±178.94	0.03	67.12±120.44	0.04
A6	117.19±178.94	0.30	335.60±120.44	0.05
A7	276.81±178.94	0.03	57.88±120.44	0.05
A8	329.84±178.94	0.02	87.34±120.44	0.42
A9	318.44±178.94	0.02	64.54±120.44	0.49
A10	80.47±178.94	0.02	79.58±120.44	0.47
A11	161.14±178.94	0.03	50.05±120.44	0.04
A13	127.75±178.94	0.04	74.84±120.44	0.05
A14	50.71±178.94	0.23	57.53±120.44	0.50
A15	129.46±178.94	0.39	40.74±120.44	0.05
A16	44.55±178.94	0.32	67.82±120.44	0.05
A17	202.55±178.94	0.04	42.69±120.44	0.51
A18	445.10±178.94	0.01	297.62±120.44	0.04
A19	28.39±178.94	0.02	156.11±120.44	0.23
A20	351.18±178.94	0.21	24.94±120.44	0.51

Values are mean ± standard error and "p" value <0.05. Note: FCF MPN/100 mL=fecal coli form most probable number; TCF MPN/100 mL=total coli form most probable number. The mean values in the same column for the same parameter were significantly different at p< 0.05.

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Table 3. The CFU/mL for each bacterial isolate in 20 sample areas.

Sample areas	*E. coli*	*Enterobacter aerogenes*	*Klebsiella pneumoniae*	*Proteus vulgaris*	*Pseudomonas aeroginosa*	*Salmonella* Sp.
A1	3×10^3	2×10^3	2×10^3	-	2×10^3	-
A2	4×10^3	3×10^3	2×10^3	-	1×10^3	-
A3	49×10^3	29×10^3	23×10^3	+	45×10^3	+
A4	50×10^3	30×10^3	36×10^3	+	37×10^3	+
A5	47×10^3	37×10^3	38×10^3	+	44×10^3	+
A6	61×10^3	40×10^3	39×10^3	+	32×10^3	+
A7	63×10^3	43×10^3	35×10^3	+	44×10^3	+
A8	18×10^3	9×10^3	6×10^3	+	4×10^3	+
A9	9×10^3	3×10^3	3×10^3	-	8×10^3	-
A10	16×10^3	8×10^3	3×10^3	+	5×10^3	-
A11	49×10^3	45×10^3	45×10^3	+	46×10^3	+
A13	41×10^3	46×10^3	44×10^3	+	42×10^3	+
A14	4×10^3	2×10^3	3×10^3	+	2×10^3	+
A15	5×10^3	2×10^3	1×10^3	+	5×10^3	+
A16	4×10^3	5×10^3	2×10^3	+	4×10^3	+
A17	6×10^3	4×10^3	1×10^3	-	3×10^3	-
A18	7×10^3	3×10^3	2×10^3	-	3×10^3	-
A19	8×10^3	3×10^3	1×10^3	-	1×10^3	-
A20	3×10^3	2×10^3	2×10^3	-	1×10^3	-

Physicochemical parameters: The calcium hardness value of river and stream water during the period of investigation ranged between 1 mg/L to 168 mg/L. The average calcium hardness was recorded as 62.25 mg/L. The magnesium hardness value of the water was by far very low or insignificant with average range of 0 mg/L to 41 mg/L. This indicated that the rivers and streams have very low magnesium concentration in all 20 sampling areas (Table 4). The nitrate value ranged between 0.356 mg/L to 2.80 mg/L. The average nitrate concentration recorded was 0.9894 mg/L. The result obtained from the laboratory test of sulfate was ranged between 2 mg/l to 145 mg/l while the average sulfate concentration was recorded as 29.95 mg/L (Table 4). The phosphate results was ranged from 4.95 mg/L to 92.8 mg/L while the mean was 26.983 mg/L. High concentration of phosphate was recorded in all sampling areas. The result obtained from this study indicated that the level of chloride ion at each sampling areas was insignificant or trace. BOD and COD were ranged between 17 mg/L to 28 mg/L and 46 mg/L to 108 mg/L respectively. The pH value of rivers and streams during the period of investigation was 6.72-8.02. The minimum value was observed at sample area 7, while the maximum value was recorded at sample area 6. At the sample areas of 12, 14, 16 and, 18, the value of pH meets the higher limit i.e. 7.84, 7.67, 7.77 and 7.84 respectively (Table 4). In this study, strong positive relation existed between BOD, COD, and FCF at r= 0.965, 0.985, 0.991, 0.981 and $p<0.01$ and also between NO^-_3, SO^{2-}_4, PO^-_4, Cl^-, Ca^{2+}, Mg^{2+} and FCF at r =0.993, 0.991, 0.993, 0.974, 0.989, 0.996 and $p<0.01$, a strong positive relation existed.

In addition, a strong positive relation existed between, BOD, COD, TUR, EC, THR and TCF at r= 0.976, 0.968, 0.993, 0.996 and $p<0.01$. Between NO^-_3, SO^{2-}_4, PO^-_4, Cl^-, Ca^{2+}, Mg^{2+}, and TCF at r= 0.988, 0.983, 0.983, 0.993, 0.988, 0.989 and $p<0.01$strong positive relation existed. The physical and chemical parameters are also strongly related. Strong positive relation existed between PH, EC and FCF at r= 0.982 and 0.981 and $p<0.01$ and also between pH, EC and TCF at r=0.984 and 0.985 and $p<0.01$ (Table 4).

Discussion

Indicator organisms are commonly used to assess the levels of pathogens in water resources. Monitoring the levels of indicator organisms is the common approach for quantifying the potential pathogen loads (Pandey *et al*., 2014). However, identifying the sources of pathogens was challenging (Dickerson *et al*., 2007). Kistemann *et al.* (2002) reported that surface water bodies were vulnerable to pathogen contamination. WDTBGD (2007) stated that coliform were discharged in high numbers from human and animal faces, but not all of them are fecal origin, as some members (eg. *Klebsiella*) of this group may sometimes grow under environmental condition. Franco and Siemintac (1993) reported that coliform bacteria was numerous and always detected in human and animal feces and also in municipal and industrial sewage. The laboratory data of coliform in this study were greater than the DEDWQS and WHO surface water guide line values (0--10 coliforms/100 mL). This indicated that the river and stream water basins crossing Gondar city are polluted.

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Table 4. Physicochemical properties of water samples.

S.A	BOD	COD	No_3^-	So_4^{2-}	Po_4^-	Cl^-	Ca^{2+}	pH	EC(µs/cm)	TUR	TH	Mg^{2+}
1	18±0.303	46±0.987	1.69±0.063	44±0.321	67±0.081	7.5±0.421	95±0.867	7.46±0.007	0.16±0.015	6.2±0.106	112±0.547	17±0.213
2	17±0.008	65±0.608	1.03±0.008	47±0.883	68±0.438	2.9±0.084	41±0.620	7.32±0.603	0.17±0.213	6.3±045	57±0.665	16±0.324
3	22±0.138	98±0.108	0.36±0.021	8±0.083	75±0.361	12±0.0.14	21±0.440	7.49±0.308	0.1±0.168	7.8±0.098	37±0.887	1±0.030
4	26±0.263	108±0.09	2.65±0.145	145±0.64	80±0.829	8.1±250	168±0.541	7.02±0.204	1.4±0.268	9.6±0.188	183±0.552	1±50.061
5	24±0.312	96±0.207	0.96±0.005	9±0.357	106±0.065	7.5±0.380	34±0.650	7.11±0.107	6.7±0.468	9.8±0.245	39±0.443	5±0.084
6	28±0.674	106±0.30	6.3±0.484	21±0.197	98±0.436	0.8±0.283	15±0.321	8.02±0.328	2.04±0.328	10±0.673	23±0.088	8±0.613
7	26±0.753	96±0.053	0.58±0.008	8±0.615	114±0.140	0.1±0.106	15±0.732	6.72±0.314	0.25±0.240	8.7±0.632	21±0.990	6±0.204
8	21±0.013	76±0.601	0.52±0.012	41±0.187	186±0.323	0.2±0.026	16±10.653	7.29±0.220	0.19±0.436	7.8±0.289	176±0.886	15±0.453
9	18±0.764	66±0.032	0.64±0.006	53±0.270	143±0.715	0±0.146	16±10.023	6.99±0.342	0.19±0.334	6.4±0.763	176±0.655	15±0.806
10	19±0.670	65±0.417	0.62±0.007	42±0.401	19±0.593	0.4±0.041	161±0.013	6.9±0.068	0.11±0.214	7.8±0.234	165±0.334	14±0.912
11	20±0.038	78±0.217	2.8±0.172	65±0.501	118±0.917	1.1±0.087	106±0.638	6,81±0.705	0.43±0.221	8.7±0.776	202±0.445	41±0.716
12	21±0.358	76±0.335	0.93±0.002	2±0.931	116±0.601	0.2±0.013	10±0.045	7.84±0.401	0.87±0.645	8.8±0.347	127±0.667	21±0.624
13	18±0.088	46±0.112	1.48±0.002	26±0.760	152±0.425	0.5±0.026	11±0.414	7.22±0.304	0.08±0.775	6.2±0.329	25±0.332	14±0.096
14	19±0.322	68±0.860	0.38±0.020	11±0.410	123±0.053	0.2±0.076	10±0.165	7.67±0.124	0.16±0.657	7.8±0.543	12±0.635	2±0.011
15	20±0.058	68±0.262	0.58±0.009	12±0.634	122±0.201	0.4±0.043	10±0.290	7.16±0.318	0.19±0.433	7.1±0.875	16±0553	6±0.041
16	19±0.027	68±0.572	0.82±0.003	11±0.928	116±0.473	0.6±0.049	14±0.073	7.77±0.090	0.23±0.223	7.2±0.554	14±0.372	0±0.037
17	20±0.349	69±0.334	0,77±0.032	12±0.786	117±0.846	0.5±0.016	23±0.065	7.32±0.807	0.18±0.554	7.1±0.438	30±0.765	7±0.070
18	18±0.568	65±0.024	1.37±0.078	10±0.135	115±0.468	0±0.001	38±0.024	7.84±0.137	0.9±0.314	7.1±0.332	46±0.348	8±0.034
19	17±0.965	65±0.033	1.43±0.121	15±0.625	115±0.316	0±0.031	9±0.620	7.43±0.008	0.13±0.668	6±0.774	21±0.458	12±0.801
20	17±0.054	64±0.021	0.5±0.031	17±0.791	115±0.860	0.1±0.368	1±0.310	7.38±0.780	0.14±0.878	6±0.099	12±0.358	11±0.765
WHO	16-18	60-80	5	400	65	250	100	6.5-8.9	8-10	5	500	150
DED	16-18	60-80	5	483	65	533	100	6.5-8.9	8-10	5	500	150

Note: The unit mg/L were used for the BOD, COD, No_3^-, $So4^{2-}$, $Po4^-$, Cl^-, Ca^{2+} &Mg^{2+} while NTU was used for turbidity.

The possible reason for this may be different anthropogenic activities like community sewerage waste, toilet waste line, municipal garbage, body and cloth wash wastes and municipal waste drainage lines etc. that flows down to these sample areas caused pollution and increased their bacterial concentration as reported by WDTBGD (2007); Fransisco and Simintac (1993). The study from Kenya reported that the coliform counts in the surface water sources were higher than the recommended minimum limit of 0 CFU/mL (Onyango *et al*., 2018).

WHO (2006) reported that the total hardness of the surface water depend on the presence of calcium and magnesium contents that enters the water bodies through residues of soaps, detergents and parent bed rock materials made up of Ca, Mg and other metal ions. The result of this study for Ca and Mg ranged between 12 mg/L to 202 mg/L with an average value of 74.2 mg/L and these values were within the limits of the WHO and DEDWQS guideline standards (i.e 500 mg/L). Generally the mean total hardness value of the sampling areas indicated that the concentration of divalent ions of the river and stream water basins that cross Gondar city was very low as compared to WHO and DEDWQS guideline values, thus the river and stream water of Gondar city are soft. Alemayehu (2001) reported that most of the parameters in upstream were low such as water pH, Sodium, Calcium, Magnesium, COD and Manganese while other parameters such as sulphate, nitrate and arsenic are high. Leta *et al*. (2004) reported that rivers in Addis Ababa were contaminated with heavy metals due to different industrial wastes. The contamination of surface water by heavy metals is a serious ecological problem as many heavy metals were toxic even at low concentrations. They are non-degradable and can accumulate in the human body. Hutton (1996) reported that turbidity was a measure of the cloudiness of water and is used to indicate water quality and filtration effectiveness. Teman (1997) also added that turbidity of natural water was caused by the presence of compounds such as clay, mud, organic matter, bacteria, and algae. WHO (2006) suggested that the flow rate of river water, soil erosion, building and road construction, forest fires, logging, and mining, urban runoff, wastewater and septic system effluent, decaying plants and animals are also some factors that increase the turbidity of water. In this study, the turbidity results were laid between 6 mg/L to 10 mg/L. The average turbidity value recorded Was 7.62 mg/L which was above the WHO recommended and DEDWQS guideline value respectively. The possible reason for this may be the flow rate of river water, soil erosion, building and road construction, forest fires, logging, urban runoff, wastewater and septic system effluent, decaying plants and animals that flows to these river and stream basins were increased the turbidity of surface (river) water as it was reported by WHO (2006) and Teman (1997). Time and Marries (2001) reported that BOD represents the fraction of dissolved organic matter which was degraded and easily assimilated by bacteria and it was a good index of the pollution of water therefore it helps indicating the suitability of water for consumption. The report also added that BOD between 16-18 mg/L of water indicates good quality of water. However, the BOD values in this study were greater that the recommended WHO and DEDWQS guideline values (16-18 mg/L). The possible reason for this may be the fraction of dissolved organic matter which were degraded and assimilated by microbes as reported by Time and Marries (2001).

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AWWWA (2000) reported that biological oxygen demand alone does not give a clear picture of the organic matter contents of the sample, the presence of various toxicants in the sample severely affects the validity of the biological oxygen demand test, hence chemical oxygen demand was a better estimate of the organic matter which needs no complex technique and also time saving. It also added that high level of COD (60-80 mg/L) of water was due to the persistence of septic or eutrophic condition or the combination of both. In this study, high COD value was recorded in all sample areas, which were greater than the WHO and DEDWQS guideline values (60-80 mg/L). The possible reason for this may be the persistence of septic or eutrophic condition or the combination of both increased the amount of COD in these sample areas as it was reported by AWWWA (2000). Generally the bacteriological parameter and physiochemical parameter data analysis of each sample areas showed a strong positive correlation because their 'r' value which ranged between -1 < 0 <1 at p<0.01.

Conclusion

In conclusion, the laboratory results of total hardness, chloride, magnesium, calcium (in 15 sample areas) and nitrate (in 19 sample areas) and sulfate were low and this indicated that the concentration of these parameters were highly reduced due to natural sedimentation and dilution. The pH and EC values were low which indicated the introduction of industry wastes and the dissolved salts (sodium chloride and potassium chloride) during the period of investigation. The value of Po_4^{2-}, C^{+2}, No_3^-, BOD, COD, TCF, FCF, CFU and TUR were high this indicated that discharge of organic pollutants, untreated wastes, run off from agricultural fields and community wastes to those river and stream water basins were very high. The pollution profile of river and stream water basins were increased from upstream to downstream and then to the midstream where the discharge of community and municipal wastes were very high.

Generally the results of the study showed that the river and stream water basins of Gondar city were severely polluted due to unsafe disposal of community and municipal wastes in to the river and stream water basins. Open ditches, sewerage waste lines and municipal garbage of the town that directly contact to the river and stream water basins should be blocked and joined to septic tanks. The city administration and stakeholders should plan and implement a suitable waste disposal and treatment strategies to alleviate its river and stream water pollution problems. Moreover, strict policy implementation should be placed in different effluents to avoid the contamination of the river water.

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