Physico-Chemical Water Quality Assessment of Gilgel Abay River in the Lake Tana Basin, Ethiopia

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Abstract
The physico-chemical parameters such as PH, temperature, electrical conductivity, total dissolved solid, turbidity, total alkalinity, total hardness, ammonia, nitrate, nitrite, phosphate, sulphate, sulfide and iron were investigated to assess the various water quality parameters along the River course of Gilgel Abay River (GAR). The value of those parameters have been evaluated with respect to guidelines provided by World Health Organization(WHO), Ethiopian drinking water quality standards(EDWQS), Canadian Council of Minister for Environment(CCME) and European Community(EC) to indicate the pollution level of GAR. Overall compliance was 58.93%. From a total of 224 samples, 132 samples (58.93%) complied with WHO guidelines and EDWQS. Turbidity, followed by iron, phosphate and sulfide were the prime river water quality issues identified in GAR. Analysis of variance was used to examine the variations of water quality parameters between the dry and rainy seasons, and the variations along the river courses of Gilgel Abay (upper, middle and lower course). The majority of the parameters showed that there is a significant variation of the water quality parameters between the dry and rainy seasons. However, the variations along the river courses of GAR (upper, middle and lower course) were statistically insignificant. This implies that the GAR water quality is influenced by anthropogenic impacts from the upper course to the lower course of the River.
Keywords: Water Quality; Physico-chemical Parameters; Gilgel Abay River

1. Introduction

Water is essential to human being, animals, and plants and without water life on earth would not exist. Humans need water not only for drinking but also for various other purposes like bathing, washing, cooking, industrial, agricultural, and recreational activities (Mulugeta, 2012). Therefore, adequate supply of potable water is necessary for proper health care and significant socio-economic development. However, water resources all around the world are under pressure and especially eutrophication is a major environmental problem. This raises the need to address the problem of water pollution with the view of monitoring the situation and formulating possible mitigating measures.

Monitoring the water quality is used to assess the usability of that water for a particular purpose, whether for human consumption, agricultural production, industry or the needs of the environment. During the last decades, there has been an increasing demand for monitoring water quality of many rivers by regular measurements of various water quality variables (Vassilis et al., 2001).

GAR is one of the major tributaries of the Lake Tana –the source of the Upper Blue Nile River, with the catchment area of 4,488 km^2 (448,799.81ha). GAR and Lake Tana are important for various socio-economic purposes. Tana sub-basin including GAR catchment has been identified by the national government as one of the growth corridors among others to achieve the country's growth transformation plan (GTP). Gish Abay is best known as the source of Abay also known as Felege Ghion is found within GAR catchment. In addition to its socio-economic purposes, GAR has the ritual and religious role. Gish Abay is a major pilgrimage site where not only local people attend the services collecting and becoming blessed by the holy water, but pilgrims from all over the country come to the source and the greatest festival when most pilgrims attend takes place on 13 January (the Ethiopian calendar), which is the celebration and holy day of Zerabruk (Oestigaard and Gedef, 2012). Currently those socioeconomic and religious activities affect the water quality of GAR.

In Ethiopia, some studies have been conducted regarding surface water pollution due to human induced impacts. In South Ethiopia, the physico-chemical characteristics of the Rift valley lakes have been studied systematically and in much detail (Elizabeth et al., 1994; Zinabu et al., 2002). This in contrast with the North Ethiopian water bodies where information on physico-chemical and microbial water quality contamination is generally scanty (Wood and Talling 1988; Elizabeth et al, 1992; Berhanu et al, 2002). Goraw et al. (2010) conducted a pilot study on anthropogenic faecal pollution impact in Bahir Dar Gulf of Lake Tana, Northern Ethiopia. Their interest was mainly on the faecal pollution impact in Bahir Dar Gulf of Lake Tana. They didn't include physico-chemical parameters and the data generated from their work could be considered spatially and temporally limited.

Recently, Tana Sub Basin Organization (TaSBO) already established water quality monitoring stations at Lake Tana within the framework of Tana-Beles integrated water resource development project (TBIWRDP). In the year 2011, annual report on Lake Tana water quality baseline monitoring was produced by TaSBO. The

Lake Tana water quality baseline monitoring report result revealed that the physico-chemical as well as biological characteristics of the major tributary rivers of Lake Tana, river mouths and lake shore areas were significantly different from open (pelagic) station of the Lake and it had been recognized that the major drivers of change of physical, chemical and microbiological water quality of Lake Tana were main tributaries and anthropogenic activities in the shore areas and the catchment at large (TaSBO,2011) .

Conducting water quality monitoring at Lake Tana is not sufficient even to manage the Lake Tana ecosystem. Monitoring the main Rivers sub-catchments of Tana Sub-basin namely: Gilgel Abay, Gummara, Rib, Megech and Dirma Rivers is increasingly important in evaluating qualities of the total ecosystem of water bodies in Tana sub-basin, in addition to the Lake Tana water quality monitoring practiced since the year 2010. Gilgel Abay River is one of the main tributaries of the Lake Tana that causes major drivers of change in water quality of Lake Tana. In the year 2012/13, in addition to Lake Tana water quality monitoring, TaSBO included main Rivers baseline water quality monitoring of Tana Sub-basin and Lake Tana sediment quality monitoring to fully determine the water quality status of Tana sub-basin as a tool for integrated water resource management in improving the sustainability of the quality and quantity of freshwater resource in Tana sub-basin. Thus we conducted this study based on this project as part of the main Rivers baseline water quality monitoring projects of Tana sub-basin. Gilgel Abay was one of a pilot project among others. We were supported by our office (TaSBO) particularly in arranging different equipment, devices, reagents and other accommodations while we conducted our field works for this study during the year 2013.

With regard to research works on Gilgel Abay, different studies have been carried out on the impact of climate change on stream flow and sediment yield of Gilgel Abay (Kim, U. and Kaluarachchi, J., 2009; Setegn *et al*., 2013).Different studies have also quantified the impact of climate change on the Gilgel Abay and the Lake Tana Basin(Tarekegn D. *et al*., 2006; Abdo KS, *et al*., 2009; Taye M. *et al*., 2011) Unfortunately, no research works have been conducted on the water quality of Gilgel Abay that can be used as a baseline water quality monitoring for Gilgel Abay. As a result of this, there is a lack of updated information concerning the Gilgel Abay River and its tributaries water quality and quantity where questions are raised from downstream and upstream communities. In view of the above facts, this study focuses on physico-chemical water quality assessment of Gilgel Abay River, Ethiopia.

To our knowledge, our present study is the first attempt in determining the water quality status of GAR. Thus it was seek to answer the following research questions:(a) Is there a significant variations in different water quality parameters along the river course of GAR(upper, middle and lower courses), (b) Is there a significant variations in different water quality parameters between the dry and wet season of GAR, (c) Is all the water quality samples of GAR compliance with WHO guidelines and EDWQS, and (d) Which of the physico-chemical water quality parameters of GAR is/are unsuitable for direct human consumption at the sampled locations or identified as the main water quality concern of GAR. To answer these questions, this research paper intends to provide comprehensive information about physicochemical water quality status of Gilgel Abay River.

The overall objective of this study was to determine the status of the GAR water quality. The specific objectives of the study were to: (a) study the physico-chemical characteristics of the GAR; (b) reveal the baseline conditions of GAR; (c) determine compliance with WHO guidelines and Ethiopian water quality standards and (d) propose recommendations for the efficient management of the river ecosystem. The physico-chemical water quality assessment of GAR will be discussed in detail in this paper.

2. Methods and Materials

2.1 Study Area Description

GAR is the largest tributary of Lake Tana Sub-basin, originates from the highland spring of Gish-Abay town. The major rivers feeding the Lake Tana are Gilgel Abay, Gumara, Ribb, and Megech. These rivers contribute more than 93% of the flow. GAR with a catchment area of 4,488 km^2 (448,799.81ha) is the largest river discharging into the Lake Tana. The main tributaries of Gilgel Abay are Koga and Jemma among others (Figure 1)

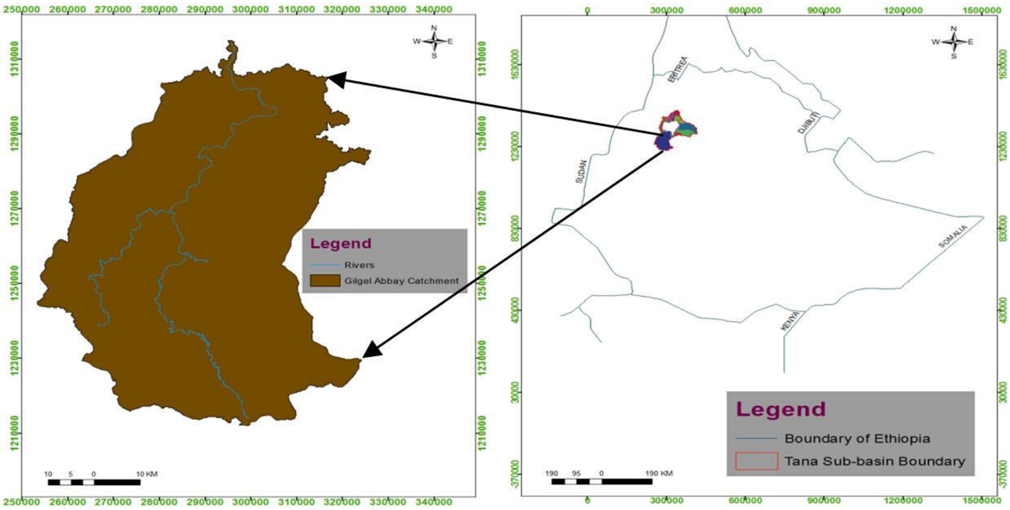

Figure1.Location Map of Gilgel Abay River Catchment (adapted from Abay River Master Plan of Ethiopian Ministry of Water Resources(MoWR,1998):Map of Gilgel Abay sub-catchment was extracted from Abay Basin shape file using ARC GIS 10.1 Software, Analysis Tool of Extract by Clip).

2.2 Sampling Site

Eight sampling stations were chosen based on baseline monitoring objectives, parts of the River where affected by development activities, parts of the River where relatively free from anthropogenic impacts, accessibility, and parts of the River where hydrological stations have been established by Ministry of Water, Energy and Irrigation.

The locations of sampling sites in Universal Transverse Mercator (UTM) coordinate system were collected from the field using GARMIN Handle Global Position System (GPS) 62 Series. These were Damot-Gish (UP-01), Koga (MD-01), Jemma (MD-02), Gilgel-Abay (MD-03), Bikolo-Abbay (MD-04), Chimba-Abay (DN-01), Abay River (DN-02) and Abay Mouth (DN-03). They reflect different activities along the watercourse of Gilgel Abay and its main tributaries. Samplings were carried out during the dry (March) and rainy seasons (July, 2013).

Table 1.Sampling Station in GAR Catchment (Collected from the field using GARMIN Handle GPS 62 Series)

No	Site Name	Site Code	Part of the River	Easting	Northing
1	Damot -Gish	UP-01	Upstream	304249	1215190
2	Koga	MD-01	Middle	286451	1257998
3	Jemma	MD-02	Middle	285879	1256279
4	Gilgel Abay	MD-03	Middle	285505	1256275
5	Bikolo Abay	MD-04	Middle	285820	1257328
6	Chimba Abay	DN-01	Downstream	300164	1294756
7	Abay River	DN-02	Downstream	294705	1313687
8	Abay Mouth	DN-03	Downstream	293925	1314066

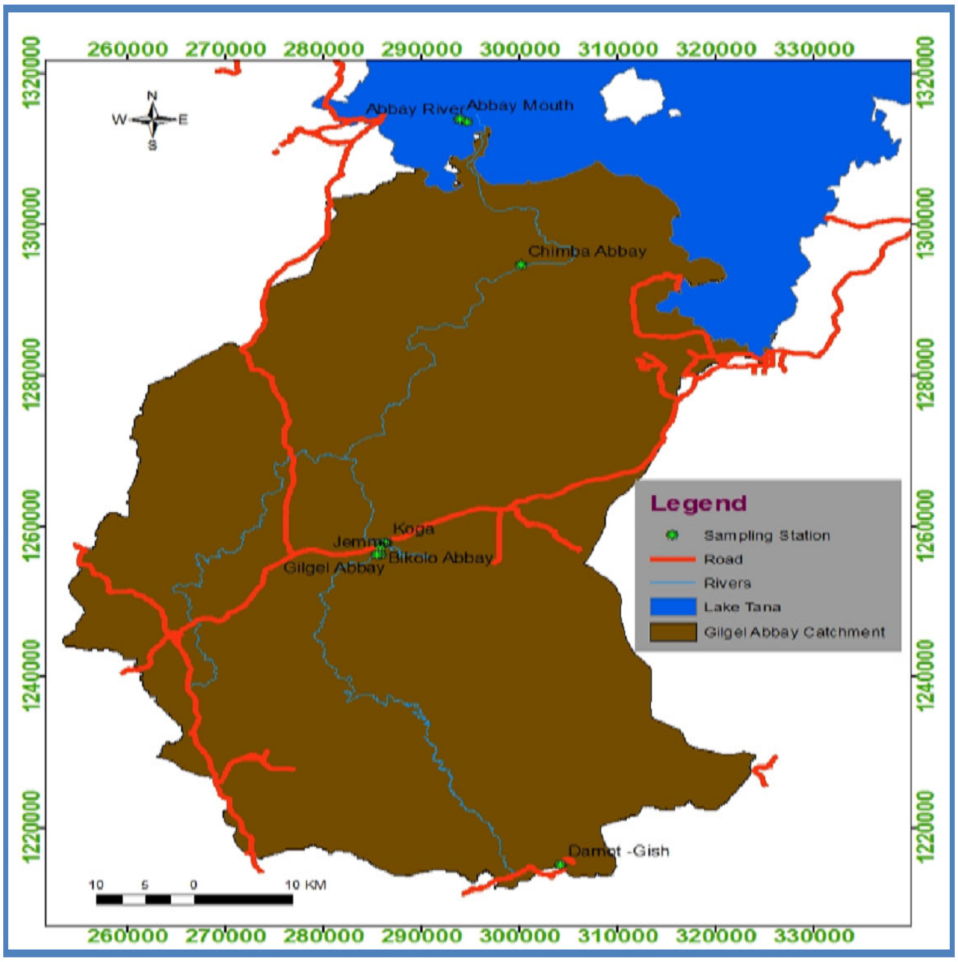

Figure 2 Location Map of Sampling Stations in Gilgel Abay River Catchment

2.3 Sampling and Laboratory Analysis

Water samples from 8 sample sites were collected. Water samples were collected from GAR using acid–washed 1 liter polyethylene bottles for chemical analysis (nutrients) based on standard procedures American Public Health Association (APHA, 1995).Analyses of total hardness, alkalinity, ammonia, nitrate, nitrite, phosphate, sulphate, sulfide and iron were immediately analyzed in the field with a mobile water analysis kit of Wag-tech international, Palintest transmittance display photometer 8000, Palintest Ltd., UK within six hours from the time of collecting the first sample.

Physical parameters, such as: PH, temperature, turbidity, electrical conductivity and total dissolved solid were determined by Wagtech Multi-Maji Parameter apparatus. In-situ measurements were taken by dipping the probe about 3-5 cm below the water surface.

2.4 Data Analysis

Data analysis is one of the most important aspects of the report, because it is the principal mechanism by which raw data are transferred into usable information to reach conclusions. Statistical analysis was done with Microsoft Excel 2007 and IBM SPSS,20.

Using Microsoft Excel 2007, differences among the water bodies/sites were tested using maximum value, minimum value, mean and standard deviation of the pooled data for the whole sites. Data were also analyzed following the guidelines provided by World Health Organization (WHO), Ethiopian drinking water quality standards (EDWQS), Canadian Council of Minister for Environment (CCME) and European Community (EC).To see whether physical and chemical parameters were in compliance with those guideline values or not, COUNTS function of Microsoft Excel 2007 was used. Numbers of samples that are found within/ outside the permissible limit were determined. Having finished the counts of samples compliance with the guideline, the level of compliance was determined by calculating the percentage.

Data analysis was performed with SPSS (one way analysis of variance) to assess or check the presence of significant variations of the selected water quality parameters among the sampling season and along the river courses of Gilgel Abay. Furthermore, data analysis was performed with SPSS to analysis the correlation between the variables of the physico-chemical water quality parameters.ARC GIS 10.1 Software was also used to prepare the location map of the study area and sampling stations of GAR.

3. Results and Discussions

Table 2. Physico-chemical characteristics of GAR water (Dry Season, 2013)

Water Quality	Unit	Sampling Sites								Desirable Standards		
		UP 01	MD 01	MD 02	MD 03	MD 04	DN 01	DN 02	DN 03	WHO	EDW QS	(EC)[a=] (CCME[b])
PH		7.54	7.96	8.56	8.53	8.54	7.74	9.02	9.6	6.5-8.5	6.5-8.5	
Temp.	oc	13.6	18	17.8	19.8	21	21	26.2	31.3			15[b]
EC	mS/cm	292	131	157	167	166	162	150	120	400		
TDS	mg/l	189	85	102	108	107	105	70	60	<600	1776	
Turbidity	NTU	28.5	116	45.6	36.5	37.9	86.4	62.4	27.5	<5	<5	
Alkalinity	Mg/l	95	95	85	85	80	95	143	108	200		
Hardness	Mg/l	110	105	90	95	100	110	115	85	400	392	
Nitrate	Mg/l	0.115	0.395	0.038	0.074	0.071	0.53	0.31	0.12	50	50	
Nitrite	Mg/l	0.014	0.026	0.013	0.013	0.009	0.025	0.036	0.016	3		
Ammonia	Mg/l	1.7	0.16	0.02	0.05	0.04	0.08	0.09	0.05	1.5	2	
Phosphate	Mg/l	0.15	0.3	0.15	0.17	0.15	0.24	0.48	0.38			0.35[a=]
Sulfate	Mg/l	12	25	9	12	11	20	24	14	250	483	
Sulfide	Mg/l	0.0	0.04	0.01	0.01	0.02	0.02	0.07	0.05			0.05[b]
Iron	Mg/l	0.92	0.82	0.1	0.11	0.11	0.22	1.83	0.89	0.3	0.4	

Table 3. Physico-chemical characteristics of GAR water (Rainy Season, 2013)

Water Quality	Unit	Sampling Sites								Desirable Standards		
		UP 01	MD 01	MD 02	MD 03	MD 04	DN 01	DN 02	DN 03	WHO	EDWQS	(EC)/ (CCME)
PH		7.31	7.93	7.93	7.7	8.13	8.23	8.18	7.99	6.5-85	6.5-8.5	
Temp.	°c	15.9	20	17.9	18.1	18.3	17.7	19.5	19.4			15[b]
EC	mS/cm	75	76	31	22	39	31	102	69	400		
TDS	mg/l	48	49	20	14	25	20	66	44	<600	1776	
Turbidity	NTU	281	791	648	784	>1000	718	>1000	515	<5	<5	
Alkalinity	Mg/l	75	230	1350	1650	750	75	1800	2000	200		
Hardness	Mg/l	75	330	1050	1250	650	1100	1500	1500	400	392	
Nitrate	Mg/l	4.14	2.25	1.92	1.46	2.28	1.9	2.36	3.68	50	50	
Nitrite	Mg/l	0.04	0.2	0.71	0.81	0.36	0.74	1.2	1.1	3		
Ammonia	Mg/l	0.14	0.4	1.7	2.2	1.1	1.8	2.6	1.8	1.5	2	
Phosphate	Mg/l	0.59	1.15	5.6	7	3.5	5.4	7.8	7.2			0.35[a=]
Sulfate	Mg/l	27	108	590	720	310	660	980	880	250	483	
Sulfide	Mg/l	0.05	0.18	1	1.3	0.7	1.4	1.8	1.4			0.05[b]
Iron	Mg/l	0.65	1.2	4.1	5.2	2.7	4.2	8.8	5.8	0.3	0.4	

The pH (hydrogen ion concentration) of GAR at all sites is slightly alkaline (Table 2 & Table 3). It ranged from a minimum of 7.31 during rainy season at Damot-Gish (UP01) to a maximum of 9.6 during dry season at Abay Mouth (DN03). During the rainy season, the pH was at its minimum and dry season it was at the maximum. The slight alkalinity could possibly be mainly due to the basic nature of volcanic rocks and it is in confirmation of an earlier study of (Melaku et al., 2007) on Tinishu Akaki River and Prabu et al.,2010) on Huluka and Alaltu Rivers of Ambo, Ethiopia. From 16 samples, 11 samples (68.75%) were found with the WHO guideline (2004) permissible limit value (6.5-8.5). The variations of PH along the courses of the river and among the sampling season were statically insignificant (0.076 and 0.072 respectively).The pH was low at Damot-Gish (UP01) and increases along the downstream at Abay Mouth (DN03). The increase might be due to the addition of sewage wastewater, and a pH value greater than 8 at the extreme downstream sampling point Abay Mouth (DN03) may possibly due to the presence of free ammonia.

The temperature value of GAR ranged from 13.6 to 31.3. C. From a total of 16 samples, only one sample (6.25%) complied with CCME guidelines (1999) for community water use. Even though the temperature values were found to be above the maximum permissible limit, it seems impossible to identify water temperature as one prime river water quality issues of GAR. Because CCME guidelines(1999) may not be applicable for tropical regions.

Conductivity varied from a minimum of 22 mS/cm during rainy season at Gilgel Abay (MD03) to a maximum of 292 mS/cm during dry season at Damot-Gish (UP01). All 16 samples (100%) complied with WHO guideline value (400 mS/cm). When compared with conductivity of River Densu in Ghana (ranged 273-402 mS/cm by Karikari and Ansa-Asare (2006), the conductivities of GAR were found to be lower. The average value of typical, unpolluted rivers is approximately 350 mS/cm (Koning and Roos, 1999). Therefore, the parameter is not the main River water quality concern and it makes the water suitable for direct domestic use. The high conductivity recorded during dry season at Damot-Gish (UP01) could be because of domestic effluent discharges from Sekela town and surface run-off from the cultivated fields which might have increased the concentration of ions. The variations along the course of the river were statistically insignificant at the 5% level (0.330). However, the variations among the sampling season were statistically significant at the 5% level (0.0001). This could be the ions were very mobile since the conductivity values during dry season for March (the peak of the dry season when flow rates were low) were almost the same at the upstream and downstream. There was a positive correlation between conductivity and TDS ($r = 0.986$). The correlation is significant at the 0.01 level (2-tailed).This was expected because the properties of conductivity are governed by the characteristics of the constituents inorganic salts dissolved in water.

TDS values varied from 14 to 189 mg/l. These values were not high compared with WHO guideline value of <600 mg/l. According to McCutheon et al.(1983), the palatability of water with TDS level less than 600 mg/l is generally considered to be good whereas water with TDS greater than 1200 mg/l becomes increasingly unpalatable. Therefore, TDS does not give cause for concern and it makes the water suitable for direct domestic use. When compared with the TDS value of Tinishu Akaki River in Ethiopia (varied 28-639mg/l) by Melaku et al.(2007), the TDS values of GAR were found to be lower. The variations along the course of the river were statistically insignificant at the 5% level (0.284). However, the variations among the sampling season were statistically significant at the 5% level (0.001).

Turbidity values ranged from a minimum of 27.5 NTU in March dry season at Abay Mouth (DN-03) to a maximum of >1,000 NTU in July (rainy season) at Bikolo Abay (MD-04) and Abay River (DN02). The turbidity value of the GAR didn't satisfy both the WHO guidelines and Ethiopia guidelines of drinking water standards. All samples (16) were not found with the WHO (2004) "suggested" value (< 5NTU) and the national standard (<5NTU). Therefore, turbidity is the main water quality concern of GAR and it makes the water non suitable for direct domestic use. High turbidity can be associated with high soil erosion from poor farming practices which result in large quantities of top soil ending up in the river after heavy rains. The variations along the course of the river were statistically insignificant at the 5% level (0.678). However, the variations among the sampling season were statistically significant at the 5% level (0.000). There was a positive correlation between turbidity and iron ($r = 0.759$). The correlation is significant at the 0.01 level (2-tailed).

Alkalinity values ranged from a minimum of 75.0 mg/l at Chimba-Abay to a maximum of 200.0 mg/l at Abay Mouth. In the absence of sufficient carbonic acid, the bicarbonate ion in the water dissociates to form additional carbon dioxide (Baird, 2000).Algae readily exploit this carbon dioxide for their photosynthetic needs, at the cost of allowing a build-up of hydroxide ions to such an extent that the water becomes quite alkaline. This can account for the high alkalinity values recorded, especially in the rainy season at downstream. The variations along the course of the river were statistically insignificant at the 5% level (0.606). However, the variations among the sampling season were statistically significant at the 5% level (0.007).

Total hardness values ranged from a minimum of 75.0 mg/l during rainy season at Damot-Gish (upstream) to a maximum of 1500.0 mg/l during rainy season at Abay River (downstream). Except the middle and the lower course of GAR, the total hardness value is well below the WHO guidelines value prescribed for drinking water. From 16 samples, 10 samples (62.5%) complied with the standard. The variations along the course of the river were statistically insignificant at the 5% level (0.369). However, the variations among the sampling season were statistically significant at the 5% level (0.001).

The nitrate value ranged between 0.038 to 4.14mg/l. The minimum nitrate value (0.038 mg/l) was observed at Jemma (MD-02) during March and the maximum nitrite value (4.14mg/) was observed at Damot-Gish (MD-01) during July, 2013. All 16 samples of nitrate (100%) complied with WHO guideline value (10mg/l). The range of nitrate value in this assessment is almost similar with the work of Dagnew et al.(2012) on the physico-chemical analyses of water quality in Amhara Region, Ethiopia, the nitrate value raged from a minimum of 0.60 mg/l to a maximum of 10 mg/l. Though the values are within the maximum permissible limits but there was an increase from upstream to downstream especially during the rainy season. These results agreed with the work of Prabu et al.(2011) on the assessment of water quality of Huluka and Alaltu Rivers of Ambo ,Ethiopia. Nitrate is generally more stable in aerated water and elevated concentration of nitrate suggests a waste source further upstream (Hem, 1985). Elevated concentrations of nitrate are more commonly associated with agricultural runoff (Maybek, 1982). Therefore high nitrate level at Damot-Gish (MD-01) during July, 2013 also suggests a waste further upstream of agricultural runoff from the source of Gilgel-Abay (Gish-Abay).

The nitrite value ranged from a minimum value of 0.009 mg/l during March at Bikolo-Abay (MD-04) to a maximum of 1.2 during July at Abay River (DN-02). Nitrite value is also well below the WHO guidelines value. Nitrite is generally unstable in aerated water and elevated concentration of nitrite is potential indicator of a waste discharge from nearby (Hem, 1985).Therefore, high nitrite level at Abay River (DN-02) is an indicator of waste discharge from the nearby recession agriculture.

The ammonia value varied between 0.02 to 2.6mg/l. The minimum ammonia value (0.02mg/l) was recorded at Jemma (MD-02) during March while the maximum ammonia value (2.6 mg/l) was recorded at Abay River (DN-02) during July. All 16 samples of ammonia (100%) complied with WHO guideline value (1.5mg/l). When compared with the ammonia value of Tinishu Akaki River in Ethiopia (ranged 0.4 -35mg/l) by Melaku et al.(2007), the ammonia values of GAR were found to be lower. Ammonia is also generally more stable in aerated water and elevated concentration of ammonia suggests a waste source further upstream (Hem, 1985). Elevated concentrations of ammonia are more commonly associated with urban waste (Maybek, 1982). Therefore, maximum ammonia value (2.6 mg/l) at Abay River (DN-02) during July is associated with wastes further from upstream Sekela town and middle Bikolo Abay town.

The phosphate value ranged from a minimum value of 0.15 mg/l during March at Jemma (MD-02) to a maximum of 7.8 during July at Abay River (DN-02). The phosphate value of GAR almost doesn't satisfy the WHO guidelines of drinking water standards. From 16 total samples, only 6 samples (37.5%) of the total complied with the European Community value (0.35 mg/l). When compared with the phosphate value of Tinishu Akaki River in Ethiopia (varied 0.15-7.8mg/l) by Melaku et al.(2007), the minimum value of phosphate of GAR was found to be lower where as the maximum value of phosphate of GAR was found to be higher. The high value of phosphate during July month is mainly due to rain, surface water runoff, agricultural runoff, washer man activity could also have contributed to the inorganic phosphate content; as well as continuous entry of domestic sewage in some area are responsible for increase in amount of phosphate. All samples of the rainy season of phosphate have values above the permissible limit. This indicates that the farmers along the riverbanks use N-P-K fertilizer, especially during the sampling period of the rainy season, which has the potential of being leached or washed into the river.

The sulfate value ranged between 9 to 980mg/l while the sulfide value ranged between 0 to 1.8mg/l. Sulfide value of GAR almost doesn't satisfy the (CCME guideline, 1999). From 16 total samples, only 6 samples (37.5%) of the total complied with the guideline value (0.05 mg/l). Traces of sulfide ion occur in unpolluted bottom sediments from the decay of vegetation, but the presence of high concentrations often indicates the occurrence of sewage or industrial wastes (Chapman, 1996). Similarly, the presence of sulfide concentration above the permissible limit could be associated with entry of domestic sewages of Sekela and Bikolo Abay towns.

The iron value ranged between 0.1 to 8.8mg/l. The minimum iron value (0.1 mg/l) was recorded at Jemma (MD-02) during March while the maximum iron value (8.8 mg/l) was recorded at Abay River (DN-02). The iron value of GAR almost doesn't satisfy the WHO guidelines of drinking water standards. From 16 total samples, only 4 samples (25%) of the total complied with the WHO "suggested" value (0.3mg/l) and the national standard (0.4mg/l). Therefore, iron is also water quality concern of GAR and it makes the water non suitable for direct domestic use. These results disagreed with the work of Dagnew et al.(2012) on the physicochemical analyses of water quality in Amhara region, Ethiopia, the iron value ranged from a minimum of 0.05 mg/l to a maximum of 0.13 mg/l. The concentration of dissolved iron in water is depend on the PH, redox potential, turbidity, suspended matter, the concentration of aluminum and the occurrence of several heavy metals notably manganese Water Resources Commission (WRC), 2003. There was a positive correlation between iron and turbidity($r = 0.906$) where as iron is negatively correlated with PH($r = - 0.152$). Hence the high values recorded in June can be attributed to the high turbidity level recorded in the same months. This implies that iron and turbidity were from similar pollution source. It is in confirmation of an earlier study of Abdul-Razak et al. (2009) on assessment of the water quality of the Oti River in Ghana.

4. Conclusion and Recommendations

4.1. Conclusion

The study has provided useful baseline information on the water quality of the GAR for the management of the River ecosystem as well as the ecosystem of the entire Tana sub-basin. The study enabled the definition of existing conditions, and provides a basis for trends detection as well as information for determining cause-and-effect relations with respect to, anthropogenic activities in and along the river of Gilgel Abay.

In general for the available data of GAR water quality baseline monitoring, the river water quality status of Gilgel Abay Catchment seems acceptable except turbidity, iron, phosphate and sulfide.

4.2 Recommendations

In light of the results of physico-chemical water quality assessment of GAR in Ethiopia, the following recommendations are forwarded:

- To have clear picture of spatial and temporal pattern of water quality of the Gilgel Abay and its environs and as tools to improve the River management, water quality monitoring schemes should be strengthened using this study as baseline information. So as to effectively assess the time trend analysis of the Gilgel Abay water pollution, sampling should be continuous for the selected sampling interval;
- Surface water pollution problem of GAR arise due to lack of proper management of watershed areas leading to excessive erosion and entrainment of nutrients and organic matter in runoff. Therefore, prioritization watershed and erosion management will help reducing the sediment and nutrient load of the water resources;
- Pollutant source inventory of GAR should be undertaken so as to know the source wise contribution of nutrients;
- The vegetative buffer zone which plays a significant role in terms of sediment retention, nutrients and heavy metals stripping and others useful ecological, hydrological, climatic functions should be delineated for Gilgel Abay and its main tributaries; and
- Further research on River Water Quality Modeling through Hydrologic Engineering Center's River Analysis System (HEC-RAS) should be done for Gilgel Abay River.

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