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RESEARCH ARTICLE

PHYSICOCHEMICAL ANALYSIS OF BARO RIVER WATER AND OTHER POTABLE WATER OF GAMBELLA TOWN, ETHIOPIA.

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Abstract

Quality drinking water is essential for life. Contaminants such as, heavy metals, organic compounds, bacteria and viruses have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-use of limited water resources. This study was conducted to assess constraints in quality management, determine contamination level of contaminants and analysis the physicochemical properties of river water and potable water. Samples were collected from different sites of the Baro River and Gambella town during spring season. The important water quality parameters such as: Color, Odor, Temperature, pH, TSS, TDS, TS, BOD, COD, DO, Turbidity, EC, Total hardness, contents of major ions (Fluoride, Chloride, Sulphate, Nitrite, Calcium, Potassium, Magnesium, Sodium) and some heavy metals were analyzed. Assessment of the water samples for pollution is made by comparison the values of all the physico-chemical parameters with the corresponding standards prescribed for drinking water by different national and international standards specially (WHO) World Health Organization standard for drinking water. Several analytical techniques including titration, flame photometer, Atomic Absorption spectrometer and multi water quality checkers were used to determine the quality of the water in the areas under investigations. The findings indicated that most of physicochemical parameters: odor, temperature, total hardness, TDS, TS,, both cations and anions, DO, COD, heavy metals for all samples were within the permissible limits of WHO for drinking water. Whereas, color, EC, TSS, BOD, temperature and the values of total turbidity of samples from Baro River were found beyond the permissible limits of WHO.

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Introduction:-

Of all the natural resources, water is unarguably the most essential and appreciated. Life began in water and spirit is nurtured by water. It is a universal solvent and as a solvent it provides the ionic balance and nutrients, which support all forms of life (Eltawilet al., 2009; Kalogirou, 2005). Water is one of the most abundant resources on earth, which covers 70 percent of the globe's surface, but most is saltwater. Freshwater covers only three percent of the earth's

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surface and much of it lies frozen in the Antarctic and Greenland polar ice. Freshwater that is available for human consumption comes from rivers, lakes and subsurface aquifers. These sources account for only one percent of all water on the earth.

All people in the world depend on this supply and a significant portion of the world's population is facing water shortages. Within a generation, the world's population will climb to an estimated 8 billion people. Yet; the amount of water will remain the same (Bishnoi and Arora, 2007). In addition to the shortage, contaminants such as bacteria, viruses, heavy metals, organic compounds and salts have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-use of limited water resources. Over one billion people lack access to clean safe water worldwide (Bresline, 2007; Idoko, 2010 and NAS 2009). In sub-Saharan Africa alone, up to 300 million rural people have no access to safe water supplies. Without safe water near dwellings, the health and livelihood of families can be severely affected (MacDonald, et al., 2005)

In Ethiopia, the dominant source of drinking water used to supply major urban and rural communities is from wells and springs. Although there are no systematic and comprehensive water quality assessment programs in the country, there are increasing indications of water contamination problems in some parts of the country. The major causes of this contamination could be soil erosion, domestic waste from urban and rural areas and industrial wastes (Gebrekidan and Samuel, 2011). Additionally, agricultural wastes such as pesticides, fungicides and fertilizer, human and animal feces, seepage from pit latrines and septic tanks, refuse dump, and municipal wastes released into water bodies are often responsible for surface water contamination. Most surface water resources accessible to household in rural areas are subjected to chemical and biological contaminations which may come from animals, septic tanks and storms water runoff (Adejuwon and Adetakun, 2012). Drinking water is a problem of for most of rural parts of Gambella region, particularly flood affected areas and some areas of the Gambella town (Hailemariam, et al., 2011). The majority communities of Gambella town and around used Baro river water for drinking, fishing, washing, small agricultural practices and other domestic purposes. But, few are used wells and springs water.

Safe drinking water is a fundamental human right and is essential for the protection of public health, environment and the communities, and a correct balance in the sensory, physical, chemical, mineral and biological characteristics of water making it drinkable (TWAS, 2002). So far, no sufficient study was conducted on the quality assessment of drinking water of the study areas, especially in terms of physicochemical, mineral and biological characteristics. In addition to this, Baro River is the main source of drinking water for human consumption and fish's source to the populations of the town and around. Hence, its quality has a direct or indirect effect on communities' health and aquatic life including fishes and aquatic plants. Thus, physicochemical and mineral examination of water in the areas is unavoidably important.

Therefore, this study was aimed to assess constraints of provision and management of drinking water, to examine the physicochemical, mineral and heavy metals characteristics, to ascertain the quality of Baro River water and potable water of Gambella town are in compliance with standards of the national and international organization like WHO water quality standards as well as to ascertain the possible causes of any contaminations and their treatment methods in order to make appropriate recommendations.

Materials and Methods:-

Description of the Study Area:-

The study area Gambella town is the capital of Gambella region which is one of the nine regional states of Ethiopia, is situated 766 km south west of Addis Ababa (the capital city of Ethiopia) and the Baro River is passing through the Gambella town and provides drinkable water to the populations (Figure 1).

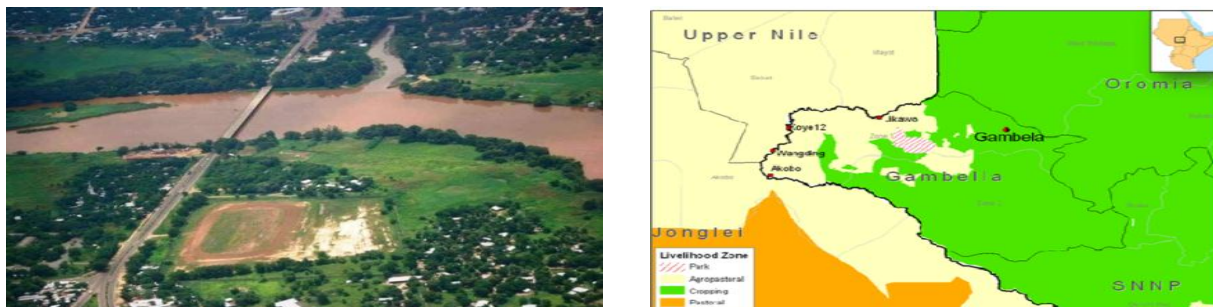


Figure 1:-Geographic location of study area (the Baro river and Gambella town at the left and the map of the region at right)

Materials, Chemicals and Reagents:-

The materials used in this study were: Conductivity meter, Oven, pH meter, Analytical balance Calorimeter, UV-Vis Spectrophotometer and AAS. The chemicals and reagents used in this study were: potassium chloride (KCl), indicators, potassium nitrate (KNO_3), sulfuric acid (H_2SO_4), Sodium hydroxide (NaOH), hydrochloric acid (HCl) and potassium hydroxide (KOH).

Experimental Methods:-

Sample Collection, Treatment and Preservation:-

Water samples were taken from different parts of Baro River and Gambella town (Figure 2). Systematic random sampling technique was adopted for the collection of the samples at a fixed distance of Baro River and from different sites of the town. A total of 10 samples were collected from different sites (Table 1). The samples have been collected in plastic bottles. The bottles were emptied and rinsed several times with the deionized water to be collected. Also, the samples bottles were partially filled with the collected water and vigorously shaken to note the order. The sample bottles were covered immediately after collection and the temperature was recorded at the same moment (Rice, 2012; Jameel et al., 2012). All the samples were stored in laboratory, freshly refrigerate at 4°C in a cooler packed with ice blocks prior to analysis to avoid microbial action affecting their concentration, contamination and gas dissolution. This was because all the analyses weren't performed at the same day.



Figure 2:-Water samples collection and Insitu measurements

Table 1:-Sample Collection sites and insitu measurements

R.N	Sites that water samples were collected	Samples codes	Collection date and time	Temperature	pH
1.	Baro river at entrance point of the town	B ₁	13/07/2017 at 03:00 pm	23	7.45
2.	Baro river at middle point	B ₂	13/07/2017 at 11:15 am	24	7.65
3.	Baro river at exit point of the town	B ₃	13/07/2017 at 10:55 am	24	7.60
4.	Drinking water of 01 Kebele	G ₁	13/07/2017 at 05:00 pm	26	7.50
5.	Drinking water of 02 Kebele	G ₂	13/07/2017 at 11:30 am	26	5.60
6.	Drinking water of 03 Kebele	G ₃	13/07/2017 at 01:05 pm	28	6.45
7.	Drinking water of 04 Kebele	G ₄	14/07/2017 at 11:00 am	23	6.35
8.	Drinking water of 05 Kebele	G ₅	14/07/2017 at 12:00 am	26	6.25
9.	Drinking water of Tower/storage	G ₆	14/07/2017 at 02:00 pm	27	6.50
10	Drinking water of treatment plant	G ₇	14/07/2017 at 04:30 pm	26	7.45

Physico-chemical Analysis:-

In this study, the physicochemical properties include: Temperature, pH, Turbidity, Odor, Electric Conductivity(EC), Color, Total hardness, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Solids (TS), Dissolved oxygen(DO), Biochemical oxygen demand(BOD), Chemical oxygen demand(COD), some major ions: Fluoride, Chloride, Sulphate, Nitrite, Calcium, Potassium, Magnesium, Sodium and some heavy metals (Chromium, Cadmium and Lead) were determined. Because the chemistry of water is sensitive to environmental changes, the following parameters were measured and recorded insitu; temperature, colour and pH. The other parameters were analyzed in the laboratory within 48 hours of collection time. Each sample was analyzed using procedures outlined in the standard methods for the examination of water and wastewater as suggested in APHA, 2005. All the chemicals used were of Analytical reagent grade.

Statistical Analysis:-

All water quality parameters: physical and chemical data were analyzed on Microsoft EXCEL. At the end, the results were compared with different national and international standards. The analysis of variance (ANOVA) was also done on EXCEL. Two factors with replication method was implemented in order to know the variation of the data between the sites in which water samples were collected and within the sample of replicate measurements.

Result and Discussion:-

Provision and quality management constraints of drinking water in Gambella; Even though naturally Gambella region has large river basins like: Baro, Alewero, Gillo and Akobo rivers, however, the rural and urban water supply coverage in the region is not match with the increased demand. In rural areas, water supply scheme condition is mal-distributed and the non-functional water points exceed the functional water points. As we observed during this research work, safe drinking water is a problem also in Gambella town because of the pipe water is not enough for the town communities and the treatment coverage is very low except some areas of the town.

The majority of people in the Gambella town collected water from unprotected Baro river water source and they often used it for different purposes such as: drinking, small agricultural activities, fishing, washing and other domestic uses. These caused different diseases like: diarrhea and respiratory infection are common.

Physicochemical Analysis:-

Temperature:-

Cool water is generally more potable for drinking purposes, because high water temperature enhances the growth of microorganisms and hence, taste, odour, colour, and corrosion problem may increase(Okoye and Okoye, 2008). In this study, the temperature measurements were conducted insitu experiment on two days starting from 10:55 am up to 05:00 pm. Temperature of the samples was in the range of 23.0 to 28.0°C (Tables 1 and 2). As far as the study areas have hot weather condition, the results show that water mean temperature of all samples was found somewhat high.

Colour:-

Colour in drinking-water may be due to the presence of coloured organic matter. The colour of samples from drinking water from Gambella town was colorless, which found satisfied the drinking water color set by WHO, but the colour of water samples from Baro River was some what cloudy (Figure 3). This shows that some humic organic substances are found in the river water.



Figure 3:-Representative photos of Water samples color of (a) Baro river and (b) Gambella town

Odour:-

Odour in water is caused mainly by the presence of organic substances. Some odors are indicative of increased biological activity; others may result from industrial pollution. The drinking water should be odorless WHO 2011. In this study, samples of water from Gambella town have no significant odor, but samples from Baro river have some spicy odour.

Turbidity:-

High turbidity may indicate the presence of disease causing organisms. These organisms include bacteria, viruses, and parasites that can cause symptoms such as nausea, cramps, diarrhea, and associated headaches (Akoto and Adiyiah, 2007). The samples from all sites of Baro river (B_1 , B_2 and B_3) have turbidity value greater than 5 NTU (Nephelometric Turbidity Units), which is more than WHO 2008 maximum desirable limit in drinking water, but the remaining samples from different sites of Gambella town ($G_1 - G_7$) have turbidity values less than 5 NTU (Table 2), which means the water in the town is in permissible region of drinking water in terms of turbidity, but not Baro river, which is may be due to the treatment processes is effective to decrease the turbidity of the river water at treatment plant. This is due to runoff from many bathing ghats, municipality solid garbage dump and other wastages in the case of Baro river, whereas some solids may remove in the treatment plant during treatment process in the case of potable water in the town.

TS, TDS and TSS:-**Total solid (TS):**

results in Table 2 indicate that samples from Baro river have higher Total solid (TS) than samples those from Gambella town potable water samples.

Total dissolved solids (TDS):

The mean total dissolved solids concentrations in Baro River was found to 438.67 mg/L which ranged from 305 – 515 mg/L in all sites of the river and the mean value of TDS for Gambella town potable water was found to 160.57 mg/L which ranged from 54 – 206 mg/L in all sites of the study area. These values were found to be within the permissible limit for drinking water standards (Table 2).

Total Suspended Solid (TSS):

WHO 2008 standard for TSS in terms of surface water is 150 mg/L. From Table 2 the TSS values for Baro River water samples in all sites were to found greater than 150 mg/L, which ranged from 236 mg/L to 278 mg/L and have mean value 252.67 mg/L. This indicates that the samples are out of the permissible limit for drinking water standards. However, the values of TSS for all samples of Gambella town were within the permissible limit for drinking water standards.

Electrical conductivity (EC):-

The results show that all the samples from Baro River and Gambella town have EC values between 395- 1420 $\mu\text{S/cm}$ (Figs 4 and 5) which more than the maximum admissible limit 250 $\mu\text{S/cm}$ set by WHO 2011, but less than admissible limit 2500 $\mu\text{S/cm}$ set by EU(1998).

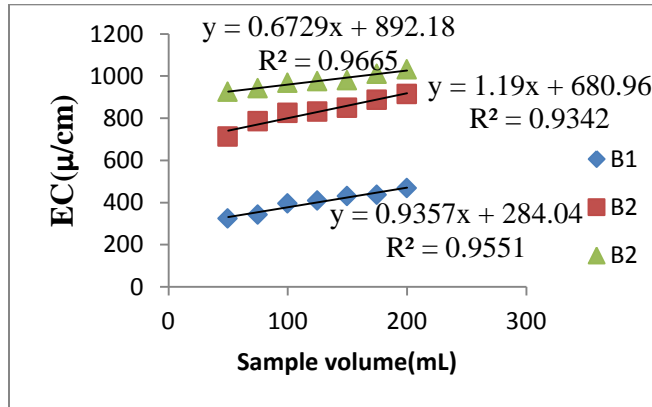


Figure 4:-EC ($\mu\text{S/cm}$) Measurement with respect to water samples volume (ml) of Baro River

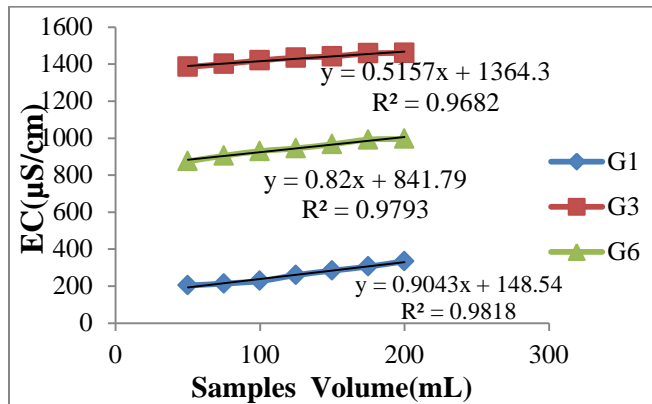


Figure 5:-EC ($\mu\text{S/cm}$) Measurement with respect to representative sample volume (ml) of Gambella town drinking water.

pH:-

pH is the indicator of acidic or alkaline condition of water status. The standard of water for any purpose in terms of pH is 6.5-7.5. In that respect the values for Baro River water are between 7.45 to 7.60 which are in the desire and nearby neutral region. Whereas, in the case of Gambella town water, the samples from two sites (G_1 and G_7) have pH values 7.50 and 7.45 respectively which are within standard region, but samples from other sites have pH values below standard/ permissible limit and indicates slightly acidic water(from 5.60 – 6.45). The difference may be due to water may react with contaminates in the pipe or/and with pipe itself, consequently the water pH is changed. Thus, the pipe may need replacement or improvement for those the later samples having acidic pH values.

Total Hardness:-

Hardness is a measure of how much calcium and magnesium is present in water (Olajire and Imeokparia, 2001) WHO Maximum allowable concentration of total hardness for drink water is 500 (mg/L CaCO_3). The values of hardness as (mg/L CaCO_3) of samples of both Baro River and Gambella town potable water are given in Table 2 and results indicate that all water samples have low total hardness, which are within the permissible limit for drinking water standards.

DO, BOD and COD:-

In the case of dissolve oxygen(DO), the tolerance limit for inland surface waters used as raw water and bathing purpose is 3 mg/l, for sustaining aquatic life is 4 mg/L whereas for drinking purposes it is 6 mg/L(Mehari, 2013) Baro River is between 2 .50 to 6.10 mg/L (spring season). DO value for all water samples from Gambella town is

between 0.55 to 4.24 mg/L. Even though almost all samples have DO value in limit prescribe, the Baro River has relatively high DO value. While in the case of biochemical oxygen demand (BOD), standard for drinking purpose is 0.2mg/L. In this research, the value of BOD for Baro River is b/n 0.31 - 0.98 mg/L, which is exceeded to the permissible value this is an indicative of a slight pollution of the river water which may be attributed to pecculation of hydrocarbon and other solid organic wastes. Whereas in the case of samples from the town, the values are between 0.06 - 0.18 mg/L for samples and which is within permissible value. A standard of COD for drinking purposes is 4 mg/L by WHO 2008 which is acceptable in terms of all water samples analyzed from all sites of both areas (b/n 0.65-3.40 mg/L).

Tab le 2:-Selected Physiochemical analyses results of Baro River and Gambella town potable water

Sam ples cod e	Parameters											
	p H	Colo r	Tempera ture(°C)	EC (µS/ cm)	TS(mg/L)	TDS(mg/L)	TSS(mg/L)	Turbidit y(NTU)	Total hardness(m g/LCaCO ₃)	DO (m g/L)	B O D (m g/ L)	CO D (m g/L)
B₁	7. 4 5	Clou dy	23	395	793	515	278	680.00	42.84	2 .50	0.9 8	2.9 8
B₂	7. 6 5	Clou dy	24	825	732	496	236	710.00	40.35	3.1 7	0.3 1	3.4 0
B₃	7. 6 0	Clou dy	24	978	549	305	244	560.00	45.68	6.1 0	0.5 4	2.6 3
G₁	7. 5 0	colo rless	26	119 5	328	204	124	0.5	50.12	1.1 2	0.0 8	1.2 4
G₂	5. 6 0	colo rless	26	864	290	178	112	Trace	43.89	0.5 5	0.1 2	0.6 5
G₃	6. 4 5	colo rless	28	142 0	164	54	110	1.00	40.80	1.8 7	0.0 6	2.6 0
G₄	6. 3 5	colo rless	23	131 2	283	153	130	Trace	44.80	0.8 5	0.1 3	1.3 1
G₅	6. 2 5	colo rless	26	594	224	129	95	2.45	47.32	2.3 0	0.1 7	0.8 7
G₆	6. 5 0	colo rless	27	930	310	206	104	1.60	41.85	4.2 4	0.1 8	1.8 3
G₇	7. 4 5	colo rless	26	121 3	290	200	90	0.5	39.23	2.1 2	0.0 7	2.7 5
WP L*	8. 5- 6. 5	colo rless	---	250	---	1000	150	5.00	500.00	6.0 0	0.2 0	4

WPL = WHO Permissible Limit

Major ions:-

Table 3 shows that all the samples comprised the good quality water with respect to all ions as recommended by WHO standard. Both anions and cations concentration in all samples was below the maximum allowable concentration. This means that the water samples from all sites have optimum amount of ions.

Table 3:-Some selected ions results of Baro River and Gambella town drinking water

Ions concentration	Water Samples										WPL *
	Baro river			Gambella town							
	B ₁	B ₂	B ₃	G ₁	G ₂	G ₃	G ₄	G ₅	G ₆	G ₇	
Sodium(mg/ L Na ⁺)	4.00	4.50	5.53	4.00	3.65	2.70	2.50	3.00	3.00	5.50	200.00
Potassium(mg/L K ⁺)	1.40	1.53	1.79	0.54	0.91	0.40	0.60	1.54	1.32	0.86	-
Calcium(mg/L Ca ⁺²)	11.42	11.13	12.54	8.43	9.02	8.98	11.42	10.76	8.43	10.27	200.00
Magnesium(mg/L Mg ⁺²)	3.43	4.02	3.65	3.87	4.21	4.41	3.92	3.96	4.56	4.33	150.00
Chloride (mg/L Cl ⁻)	9.54	10.6	8.96	6.74	7.35	6.36	5.57	5.43	6.32	7.86	250.00
Nitrite (mg/L NO ₂ ⁻)	0.046	0.041	0.037	0.006	0.004	0.005	0.005	0.007	0.004	0.005	0.2
Fluoride(mg/L F ⁻)	1.47	1.53	1.21	0.03	0.06	0.05	0.02	0.04	0.07	0.03	1.5
Sulphate(mg/L SO ₄ ²⁻)	12.13	18.10	21.90	8.84	10.25	16.70	9.50	15.33	20.32	11.16	250.00

Heavy Metals Analysis:-

In this study, the concentration of Cadmium (Cd), Lead (Pb), and Chromium (Cr) were determined in water samples collected from Baro River and Gambella town potable water, in order to establish their baseline levels. The concentrations of heavy metals: Cd, Cr, and Pb in the drinking water samples analyzed are presented in Table 4 and the results indicated that all analyzed heavy metals concentration were below detection limit and trace except chromium at two water samples and lead at one water sample. This means that all water samples are almost free from heavy metals contamination.

Table 4:-Some heavy metals analysis results of Baro River and Gambella town drinking water

Elemental concentration	Water samples #										WPL	
	Baro river			Gambella town								
	B ₁	B ₂	B ₃	G ₁	G ₂	G ₃	G ₄	G ₅	G ₆	G ₇		
Chromium (mg/L Cr)	BLD	0.002	BLD	0.001	BLD	BLD	BLD	BLD	BLD	BLD	BLD	0.05
Cadmium (mg/L Cd)	0.001	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	0.01
Lead(mg/L Pb)	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	BLD	0.30

BLD = below detection limit

Statistical Analysis:-

Statistical evaluations: mean, range, standard deviation, variance, skewness, maximum and minimum values sum and differences for all physico-chemical parameters of Baro River water samples and Gambella town potable water samples have done. All statistical evaluation results indicated that there were some significant variations among the samples of different areas, but no significant variations within a sample of replicate measurements.

Conclusion and Recommendations:-

Conclusion:-

From this research work the authors have been seen that there are constraints on provision and water quality management of the study area such as: lack of treated /pipe water in the town, shortage of water treatment plant in the town, lack of awareness of communities on the habit of using house water treatment methods (like boiling and using water agar) and direct use of unprotected Baro river water for different purpose including drinking. Results indicated that most of the water parameters values for samples of Gambella town drinking water were somewhat better than those from Baro river water samples; this shows that the town water is more quality than the river. TSS, Color, EC, BOD and the values of Turbidity of samples from Baro river were found beyond the permissible limit of WHO standards. The pH and EC values were out of the WHO permissible limit for the case of samples from Gambella town. The remaining parameters for all samples from both areas did comply with the WHO permissible limit for drinking water. The contents of heavy metals (Cr, Cd and Pb) in water samples were below detection limit of the instruments except Cr for two samples and Pb for one sample which have been also within permissible limit. However, it is difficult to conclude that the water is certainly fit or unfit for drinking purposes because it needs additional study for microbiological parameters and testing of other heavy metals like Hg, As, Zn, etc, but we can conclude that direct use of the Baro river water without any form of treatment is not recommendable because it showed that some pollution and have high amount of turbidity, TSS, EC and BOD and the drinking water of the town need some correction on either the pipes and storages.

Recommendations:-

We hereby recommend that: (1) water from rivers should be treated before supplying to the public (2) water from the rivers should be boiled before drinking or treated by other treatment mechanisms. (3) the provision of public water(pipe water) supplied by government should be addressed all areas/kebeles in the town. (4) if boreholes are to be provided, there should be proper geological survey before sitting the borehole. (5) dissemination of information for public awareness on environmental safety including increased use domestic refuse dump sites and indiscriminate use of agro-chemicals, which are washed to the rivers during the wet season, so that there should be proper wastage system of domestic garbage and protection mechanisms of the river. (6) It is very much necessary to conduct more research on other parameters particularly microbiological properties of both the river, town water and other areas of the region.

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