Physico-Chemical Analysis of Drinking Water (in case of Mettu town, Southwest Ethiopia)

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Abstract- Due to various natural and anthropogenic activities, quality of water was deteriorated in most towns of the country. These changes make the community to depend on unsafe and poor water consumption. Under the present investigation some physicochemical parameters of water from Mettu town for drinking purpose was characterized. The analyzed laboratory result of some heavy/trace metals from the town were Zn (from source point, tap and distribution was 0.06429 ± 0.00242, 0.00759 ± 0.00235 and 0.03594 ± 0.00238 respectively), Pb (from source point, tap and distribution was respectively 0.04348 ± 0.04376, 0.11141 ± 0.04450 and 0.07744 ± 0.04413). Among the three heavy metals the concentration of Lead (Pb) recorded was above the maximum permissible limit of lead in drinking water (0.01 mg/L) according to WHO standard. Some selected laboratory result of physicochemical parameters was pH [Ms (6.44), Mt (6.61) & Md (6.32)]. Electrical Conductivity (μS/cm^{-1}) [Ms (274), Mt (259) & Md (267).Turbidity (NTU) [Ms (8.21), Mt (5.63) & Md (5.87). Comparatively the maximum value for almost all physicochemical parameters were recorded at Mettu town which indicates further treatment process needs for this town.

Index Terms- Physicochemical, Heavy metals, Drinking water

I. Introduction

Water is one of the most important compounds that constitute the largest part of life on earth. 70.9% of the surface of our planate is covered by water. Of which; 97% of the total water wealth is concentrated in oceans while ice caps comprises 2.4%. Other surface water bodies such as rivers, lakes and ponds constitute 0.6% and 1.6% retained underground (Hirsch *et al*., 2006).

It is the most crucial thing that life can exist on earth and involved for several purposes including drinking, cleaning, dissolving, oxygenating, photo-synthesis, transportation, habitat formation, etc. (WHO, 1992).

Drinking water is the second prerequisite for life next to oxygen (Shan *e al*., 2013; Roohul-Amin., *et al*., 2012**).** However, majority of the world's population still live without access to healthy water due to continuous contamination with several contaminants such as sewage and industrial effluents (Goel, 2006). The contamination of drinking water with physical, chemical and microbial contaminates have been posing serious threats to millions of people across the globe. In both the developing and developed nations, microbial pathogens recognized as a cause of severe morbidity and mortality of individuals through periodic outbreaks of diarrhoeal diseases (Corso *et al*., 2003; Mac-Kenzie *et al*., 1994 and Bouzid *et al*., 2008).

In addition, water sources including rivers, springs, wells and underground water sources have increasingly become polluted with municipal sewage, industrial waste, industrial toxics, heavy metals, fertilizers, chemicals, radioactive substances, land sediment and so on (Bartram and Balance, 1996**).** Physicochemical parameters such as turbidity, pH, temperature, nitrate and others with respect to water quality are widely accepted as other critical water quality parameters describing the quality of drinking water. In Ethiopia, access to improved water supply and sanitation is very low and it is estimated to be 38% and 12% respectively (UNICEF and WHO, 2008).

In the country, over 60% of the communicable diseases are assumed to be caused by poor environmental health conditions that emerged from unsafe and inadequate drinking water supply besides from poor hygienic and sanitation practices (MOH, 2007).

The WHO Guidelines for Drinking Water Quality (GDWQ) describes the need to protect public health through the adoption of a water safety plan (WSP). It establishes general guidelines for drinking water quality providing a common point of reference for all nations to determine the safe level of drinking water. This necessitates proper protection of water supply from contamination and the need for regular surveillance of water resources. Frequent examination of indicator organisms remains one of the best methods of assessing the hygienic condition of drinking water (Mengesha Admasu *et al.,* 2004). Thus, surveillance of drinking water is imperative to minimize such contaminations and ensures continuous supplies of healthy water to the people of Mettu town, Illubabor zone, Southwest Ethiopia.

Statements of the Problem

Water bodies usually consist of different bio-assimilation and bio-accumulation of metals in aquatic organisms which have long-term potential implications on human health and ecosystem. Heavy metals in different water bodies and sediments are most investigated recently.

The toxicity of these heavy metals has long been concerned since it is very important to the health of people and ecology. They also accumulate in water at toxic levels as a result of long-term application of untreated wastewaters (Bartram and Balace, 1996; Ahmed et al., 2010). Informal information speaks; drinking water quality of Mettu, Bedelle and Gore is not good enough to drink and mostly become contaminated with variety of physical and biological contaminants that usually result in the establishment of frequent diarrhoea in the inhabitant peoples.

In addition, there are no scientific evidences that show the quality status of drinking waters from these areas in the literatures. Consequently, the present study is aimed at evaluating the physicochemical parameters and such as turbidity, trace metals (Cu, Zn, Cd, Ag and Pb), pH, temperature; nitrate, phosphate, chloride, TDS, TSS, total hardness, sodium, potassium with respect to water quality parameters are widely accepted as other critical water quality parameters describing the quality of drinking water of Mettu town southwest Ethiopia for the first time.

Significances of the study

The study is designed to conduct the determination of physicochemical quality of drinking water of Mettu, Bedelle and Gore towns from December, (2013) to April, (2014). The work will help to assess the pollution status of drinking water which is being supplied to inhabitants of the
already mentioned selected towns.

Similarly, the study is also important for providing scientific evidences before someone using tap water of the towns for drinking purposes that help them to take care from being infected.

Materials and Methods

Description of study area

Mettu is found in south-west Ethiopia of Oromia region. Mettu is found 600 km from Addis Ababa south west part of Ethiopia and it is 170 km from Gambela region on the way to Jimma town. Mettu is the capital city of Illubabor zone.

Sampling Point Selection and Location

Three sampling points/sites from the town were selected for analyzing the physicochemical water quality parameters as well as some selected heavy metals concentration of drinking water. The selected sampling points were: Source point, Tap water and Distribution or reservoir point.

Water sample was collected from each sampling points. To collect water sample from each sampling point different points was selected to represent the whole sample and finally composite sample was collected and was transported to the laboratory for analysis. Water samples were collected three times from each sampling points by using polyethylene and glass bottles. Water sample was carried out during the dry time, single volume of water taken all at one. Once the sample is collected from each sampling point, all physicochemical parameters selected were analyzed both in the laboratory and at the field. Water

Water samples from each of four sampling points were collected by direct immersion of bottles into the river and handled by rope. Before collection of water samples, bottles were washed with concentrated nitric acid and distilled water to avoid contamination.

Methods, Materials and Chemicals

Chemicals and reagents used during analysis periods were analytical grade. For all sampling points pH of the water sample was measured by using pH meter (pH 600 Milwaukee (Mauritius) at in-situ. pH meter was calibrated by buffer standards at pH 4, 7 and 10 (AWWA, 2002).

Electrical conductivity (EC) was measured by digital conductometer. Total Alkalinity was measured by the titration method using methyl orange indicator and titrating with standardized sulphuric acid. Calcium was measured by titration using Murexide indicator with standardized EDTA solution as a titrant. Chloride was measured by titration using Potassium chromate indicator and with standardized silver nitrate solution. Turbidity was measured by digital Turbidimetrc 2100A instrument. Total dissolved solids (TDS) were measured by Digital Conductometer. Magnesium was measured by titration method using Eriochrome Black T as an indicator and titrating with standardized EDTA solution.

Total hardness was measured by titration using Eriochrome Black T as an indicator and with standardized EDTA solution. Ammonia (by stannous chloride method), nitrate, and phosphate (by Phenate method) were measured by Uv-vis spectrophotometer (ELICO SL 160, INDIA). Sulphate was determined by Gravimetric Method with Ignition of Residue. Potassium and sodium was measured by Flame Emission Spectrophotometer (ELICO CL 378 Flame Photometer, India). For Trace metals analysis Flame Atomic Absorption Spectrometer (Analytikjena model nov AA 300) was used.

The analyzed laboratory result taken from all sampling points was evaluated and compared with the WHO and the Draft Ethiopian drinking water quality standards, EPA standards and interpreted in accordance with the result obtained from the laboratory and with the maximum WHO allowable limits.

Results and Discussions

Determination of Heavy Metal Concentration

Concentration of heavy metals (Pb, Cu and Zn) for all sampling points was determined using Flame Atomic Absorption Spectrophotometer (Analytikjena model nov AA 300) at Jimma University; Applied Chemistry Laboratory.

Method Optimization Process

During the optimization process, different digestion procedures that employ HNO_3, $HClO_4$ and H_2O_2 mixtures were selected from literature and assessed (AWWA, 2002). The optimization procedure was selected on the basis of clarity of digestate, minimal acid volume consumption, digestion temperature and minimum time consumed. The optimum procedure chosen based on these criteria required a total of 3 hours for the complete digestion of 50 ml of water sample with 6 ml HNO_3, 4 ml $HClO_4$ and 2 ml H_2O_2.

Table 1.1: Optimization process for different volumes of acids, temperature and time

Amount of sample used	Volume of reagent consumed	Temperature of digestion	Time consumed for complete digestion	Color Observed
50 ml	10 ml HNO_3 7 ml $HClO_3$ 2 ml H_2O_2	125 °C	3 hrs	Yellow color solution
	6 ml HNO_3 4 ml $HClO_3$ 2 ml H_2O_2	125 °C	3 hrs	Yellow color solution
	4 ml HNO_3 2 ml $HClO_3$ 2 ml H_2O_2	125 °C	3 hrs	Yellow color solution
50 ml	10 ml HNO_3 7 ml $HClO_3$ 2 ml H_2O_2	140 °C	2 hrs	Light yellow color solution
	6 ml HNO_3 4 ml $HClO_3$ 2 ml H_2O_2	140 °C	2 hrs	Yellow color solution
	4 ml HNO_3 2 ml $HClO_3$ 2 ml H_2O_2	140 °C	2 hrs	Yellowish color solution
50 ml	10 ml HNO_3 7 ml $HClO_3$ 2 ml H_2O_2	185 °C	3 hrs	Clear solution
	6 ml HNO_3 4 ml $HClO_3$ 2 ml H_2O_2	**185 °C**	**3 hrs**	**Clear or white solution or colorless solution**
	4 ml HNO_3 2 ml $HClO_3$ 2 ml H_2O_2	185 °C	3 hrs	Very light yellow color solution

Method Validation Process

Calibration and Linearity of Instrumental Responses

The calibration curves for each selected heavy metals was setted to ensure the accuracy of the Atomic Absorption Spectrophotometer and to confirm that the result of measurements were true and reliable.

Table 1.2: Standard calibration points for absorbance of Cu, Zn and Pb

For Mettu town					
Metal	**Wavelength (nm)**	**Calibration Conc. (µg/mL)**	**Regression Coefficient (R^2)**	**Linear Range (µg/mL)**	**IDL(µg/mL)**
Copper	324.7	IB , 1.0, 2.0, 4.0	0.999	0 - 4	0.0010
Zink	213.9	IB, 0.5, 1.0, 1.5	0.998	0 - 1.5	0.0042
Lead	217.0	IB, 2.5, 5.0, 7.5	0.999	0 - 7.5	0.0081

IB- Instrument blank

Method Detection Limit (MDL)

MDL defined as the "minimum concentration of substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, and is determined from analysis of a sample in a given matrix containing the analyte. To determine MDL value at least seven replicate (in this particular case nine replicates were analyzed) determinations of water and blank was spiked with respective analyte and the signal was taken for each analyte by using the following equation.

MDL = SD x t

Where: - MDL- method detection limit

SD- standard deviation of measured replicates

t- Student's t- value measured at 99% confidence level

(In this particular case N=9, t=2.821)

Instrumental Detection Limit (IDL)

Instrument Detection Limit (IDL) is also defined as the concentration equivalent to a signal, due to the analyte of interest, which is the smallest signal that can be distinguished from background noise by a particular instrument. The IDL should always be below the method detection limit, and is not used for compliance data reporting, but may be used for statistical data analysis and comparing the attributes of different instruments (Erich P., 2010),

Table 1.3: Results of IDL and MDL for water sample

Metal	**IDL (ppm)**	**MDL (ppm)**
Cu	0.0010	0.0042
Zn	0.0023	0.0042
Pb	0.0070	0.0081

Recovery Test

One of the most important quality assessment tools is testing the recovery of a known addition or spike of analyte to a method blank, field blank or sample. In situations where of standard reference materials are not available it is common practice to perform spiking experiment to evaluate the efficiency of an acid digestion method (Erich P., 2010). Performance of the selected digestion method for water sample measured by conducting recovery test on spiked samples using composite standard solution of the analyzed metals. Percent recovery for the metals was calculated using the following equation:-

$$R = \frac{Cs - C}{S} x\ 100$$

Where: - R- percent recovery.

Cs- measured concentration of a metal in the spiked sample.

C- Average concentration of the metals in the samples (water or sediment)

S- Concentration equivalent added to the spiked sample

Table 1.4: Determination of percent recovery of water sample

Metal	**Cs**	**C**	**S**	**% R**
Cu (mg/L)	1.20	0.29	1.05	**86 $\pm$ 0.0115**
Zn (mg/L)	1.48	0.63	1.05	**85 $\pm$ 0.0456**
Pb (mg/L)	3.51	2.51	1.05	**95 $\pm$ 0.0762**

Analysis of Metals in Water Samples

The average results of heavy metals analyzed for water sample from all sampling points and from all replicate analysis were summarized in the following table.

Table 1.4: Results from laboratory analysis of heavy metals in water sample

Heavy metals	Sampling Points		
	Ms	**Mt**	**Md**
Cu (mg/L)	Bd	Bd	Bd
Zn (mg/L)	0.06429 ± 0.00242	0.00759 ± 0.00235	0.03594 ± 0.00238
Pb (mg/L)	0.04348 ± 0.04376	0.11141 ± 0.04450	0.07744 ± 0.04413

Note: Ms-Mettu Source, Mt-Mettu tap and Gt-Gore tap, Md-Mettu distribution
Bd- below detection limit of an instrument (0.001 ml/L)

Data Analysis and Interpretation

The analyzed laboratory result taken from three sampling points was evaluated based on the average mean values of the three replicates for each physiochemical water quality parametric values and was compared with the WHO and the Draft Ethiopian drinking water quality standards, and interpreted in accordance with the result obtained from the laboratory analysis with the maximum WHO allowable limits. The interpretations of the result of physicochemical values were depending on the summarized table below.

Table 1.5: Laboratory results for physicochemical water quality parameters of water sample

No.	Parameters	Ms	Mt	Md
1	pH	6.440	6.610	6.320
2	Conductivity (μS/cm^{-1})	274.000	259.000	267.000
3	TDS (ppm)	250.000	200.000	230.000
4	Alkalinity (ppm)	205.000	182.000	200.000
5	Potassium (mg/L)	4.695	4.595	3.457
6	Ammonia (mg/L)	0.0645	0.0265	0.078
7	Sodium (mg/L)	18.650	15.650	15.100
8	Nitrate (mg/L)	0.048	0.086	0.062
9	Sulphate (mg/L)	0.000	0.000	0.000
10	TSS (ppm)	68.000	66.000	62.000
11	Phosphate (mg/L)	0.040	0.030	0.040
12	Chloride (mg/L)	21.300	23.430	24.930
13	Turbidity (NTU)	8.210	5.630	5.870
14	T. hardness (ppm)	450.000	435.000	428.000
15	Calcium (mg/L)	10.841	14.591	11.234
16	Bicarbonate (ppm)	270.000	246.000	237.000
17	Carbonate (ppm)	320.000	293.000	256.000
18	Magnesium (mg/L)	14.390	13.190	13.740

Conclusion and Discussion

From the laboratory analysis result, the average concentration value of copper was not detected that means it is below the detection limit of the instrument i.e. below 0.001 mg/L. The average value for zinc metal ranges from 0.0028 mg/L to 1.036 mg/L, the value was below the maximum standard of zinc metal in drinking water which is 3.0 mg/L. The average concentration value for Lead metal ranges from 0.044 mg/L to 0.111 mg/L, the value was above the maximum permissible limit of lead in drinking water (0.01 mg/L). The average pH value of water ranges from 6.32 to 6.61 which are almost acidic which is less than 7. Normally natural water usually used for drinking purpose has a pH value between 6.5 and 8.5. Mettu site is almost out of this range i.e. less than WHO and the draft Ethiopian drinking water guidelines value.

While there are natural variations in pH, many pH variations are due to human influences. When water has a pH that is too low, it will lead to corrosion and pitting of pipes in plumbing and distribution systems. This can lead to health problems if metal particles are leached into the water supply from the corroded pipes.

Electrical Conductivity value ranges from 259 µS/cm-1 to 274 µS/cm-1. All the recorded values are within the WHO maximum permissible value and the draft Ethiopian drinking water guidelines for drinking purpose (2500 Scm-1).

The average turbidity value ranges from 5.63 NTU to 8.21 NTU which is by far greater than the maximum allowable limits of turbidity for drinking purpose (5 NTU). The average value of total dissolved solids (TDS) from 200 mg/L to 250 mg/L. These all values lie almost within the WHO maximum allowable drinking water quality ranges and the draft Ethiopian drinking water guidelines 1000 ppm and 1176 ppm respectively.

The average TSS value of water ranges 62 mg/L to 68 mg/L. These all values lie almost within the WHO maximum allowable drinking water quality ranges and the draft Ethiopian drinking water guidelines 500 ppm.

The average result of total hardness (TH) for the three towns ranges from 428 mg/L $CaCO_3$ to 450 mg/L $CaCO_3$. All values obtained are within the standards of WHO 500 mg/L $CaCO_3$ but the result from Mettu town was greater than Ethiopian drinking water guidelines standard which is 392 mg/L $CaCO_3$. All the average values are categorized under slightly hard water range ((120- 180) mg/L $CaCO_3$).

The laboratory result indicates that the average value for alkalinity ranges from 182 mg/L to 205 mg/L. This result is slightly greater than the standards. This may indicate that drinking water from Mettu town contains nutrients contributing alkalinity like OH^-, CO_3^{2-} and HCO_3^-.

From the laboratory result the average value obtained for potassium ranges from 3.457 mg/L to 4.695 mg/L. Comparatively the maximum value was recorded at Mettu town, even though all the recorded values lies within or below WHO, EPA and draft Ethiopian drinking standard guidelines for drinking purpose (30 mg/L). The average concentration value of ammonia ranges from 0.026 mg/L to 0.078 mg/L. All the recorded values are below WHO standards for drinking purpose which is 1.5 mg/L.

The average value recorded for sodium ranges from 15.10 mg/L to 18.65 mg/L. All the recorded average values lie within the range of or below WHO standard for drinking purpose which is 200 mg/L.

The analyzed laboratory result of Nitrate ranges from 0.048 mg/L to 0.086 mg/L. All the recorded values was by far less than the maximum allowable limit WHO standard (50 mg/L) and Draft Ethiopian Drinking Water Standards for drinking purpose (50 mg/L).

The analyzed laboratory average result of phosphate ranges from 0.03 mg/L to 0.04 mg/L. All the recorded average values was by far below the WHO (50 mg/L) and draft Ethiopian drinking standard maximum allowable limit value for drinking purpose.

The average chloride concentration value recorded from laboratory analysis ranges from 21.30 mg/L to 24.93 mg/L. The recorded values was by far less than the that of WHO standard value and EPA standard value of water for drinking purpose (250 mg/L).

The average value recorded for calcium ranges from 10.841 mg/L to 14.591 mg/L. All the recorded average value was below the WHO's maximum permissible value of calcium in water for drinking purpose 200 mg/L. The average concentration value of magnesium ranges from 13.19 mg/L to 14.39 mg/L. All the recorded values lies below the WHO maximum allowable for drinking purpose limits which are 150 mg/L. The average concentration value of carbonate ranges from 256 mg/L to 320 mg/L. All these values lie within the WHO and EPA standard value of water for drinking purpose. The average concentration value of bicarbonate ranges from 237 mg/L to 270 mg/L.

Recommendation

The increasing value of some physicochemical water quality parameters from the laboratory analysis especially Turbidity, Total alkalinity and among heavy metals like Lead was recorded as maximum value when compared with reference standards (WHO, EPA and draft Ethiopian drinking standard). As it was pointed out in the literature review part, high turbidity level of water indicates water that lacks transparency of ions and other important substances which is important for drinking as well as for plants and animals which live inside water body and also it is not good for irrigation purpose.

Similarly, high turbidity level indicates there exists high amount or level of suspended solids in water bodies. Especially, high turbidity value was recorded at Mettu town of source point.

Total alkalinity value of the town was recorded greater than the standard values. Maximum level of alkalinity may indicate that drinking water or any other water contains nutrients contributing alkalinity like OH^-, CO_3^{2-} and HCO_3^-, but from the laboratory result, the pH value recorded was below 7.0 which is not basic; this may indicate nutrients contributing alkalinity for this town may be due to CO_3^{2-} and HCO_3^-. Among heavy metals Lead was recorded above the maximum limit at all sites. This increment may be due to improper use or long term use of the pipe for transporting/distributing of water.

Generally, the increment of all parameters may be controlled by treatment process; especially water treatment plant of Mettu town still has a problem. The concerned body should take immediate mechanism in order to control increment of contaminants getting into water bodies and also revise their water treatment process.

The final recommendation to the town (Mettu) will be, please take into consideration this research value and check your water treatment process or mechanism.

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