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## Assessment of Drinking Water Quality and Treatment Plant Efficiency in Southwest Ethiopia

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## ABSTRACT

Treatment of public water supply is an indispensable element in providing safe drinking water and to minimize the prevalence of waterborne diseases. However the efficiency of treatment plants was not known in Ethiopia. This study aims to determine drinking water quality and the efficiency of treatment plants in Southwest Ethiopia. Eighty four water samples were collected from the sources to household taps during dry and rainy seasons. A pre-tested and calibrated multi-parameter probe and turbidity meter were used to measure on the spot. Samples were transported at 4 °C and analyzed according to standard methods and procedures. The majority (87.4%) of physicochemical parameters were in compliance with the WHO standard. However, free residual chlorine, coliform and fluoride were not within the recommended limits. WQI of Agaro and Metu were in good category; whereas Jimma water was in poor category. The log removal value (LRV) and efficiency of treatment plants were 73.6%, 48.4% and 74.1% effective in overall pollutant removal in Jimma, Agaro and Metu, respectively. The treatment plants were still technologically appropriate to deliver safe water to the public, but focusing on technical skills on water treatment and quality monitoring may improve the observed negative findings.

## 1. Introduction

The government of Ethiopia was striving to enhance all national efforts towards the efficient, equitable and optimum utilization of water resources to access a universal coverage in drinking water [1]. In the meantime, the Ministry of Finance and Economic Development (MoFED) reported that, the national coverage for improved water sources reached 82.4% urban and 66.3% rural; and 90.0% urban and 65.9% rural in Oromia regional, state [2]. On the contrary, diarrhea was the second largest single cause of under-five child mortality (88/1000 live births) and morbidity due to diarrhea accounts 31%, mainly due to lack of quality water sources [3]. Moreover, Acute Watery Diarrhea (AWD) was becoming a major public health problem both in urban and rural settings of Ethiopia [4]. This paradox indicated, delivery of safe drinking water service to all people is the greatest development setback in the 21<sup>st</sup> century in developing countries including Ethiopia.

The production and supply of safe drinking water to consumers at all times constitutes a major challenge to water authorities. This task is more challenging in tropical countries like Ethiopia, where strong seasonal variations prevail. This variation can affect the efficiency of water treatment, water supply pattern and the quality of water in the water distribution system too [5].

Nowadays, the quality of drinking water is degrading due to large scale application of Agrochemicals, direct pollution by untreated sewage and infiltration of effluent from sewage treatment plants and storage pits [6]. However, the efficiency of existing water treatment systems to remove potential pollutants from the above sources in different seasons were not clearly known [7].

Conventional water treatment and bore hole are the dominant drinking water sources for urban settings in Ethiopia. But, studies are very limited and even the existing studies focused on springs and wells [8-10]. Despite, the alarming rate of water pollution and the huge disease burden associated with unsafe water supply, very little effort has been done to investigate the efficiency of existing water treatment systems in developing countries where Ethiopia is the case in point. Thus, the focus of this research was to determine the quality compliance of drinking water

with the WHO guideline value. Although, to calculate WQI for all town water supplies and determine the efficiency of existing water treatment systems in removing selected water quality parameters in Southwest Ethiopia.

## 2. Experimental Methods

## 2.1 Study Design and Area

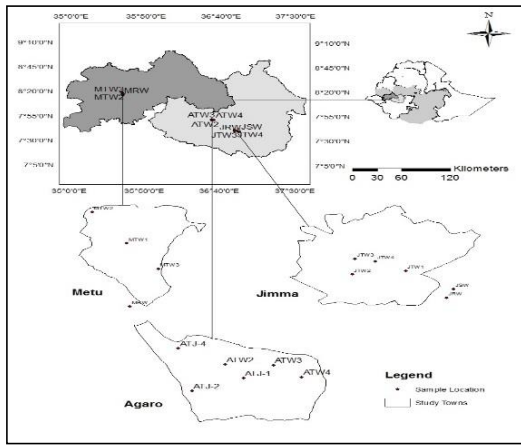
A longitudinal study was conducted to determine the drinking water quality compliance and the treatment efficiency of municipal drinking water sources in the dry and rainy seasons in Jimma, Agaro and Metu towns, Southwest Ethiopia (Fig. 1). Gilgel Gibe River was the source of raw water for Jimma town. While the final treated water is lifted via high-lift pumps to a reservoir situated in the Aba-Jiffar palace for onward distribution to the town administration. The treatment plant has an intake structure with four low-lift pumps and the aerator structure is a concrete cascade in two parallel units. The plant consists of sedimentation, filtration and chlorination structures. It served the town for about 20 years and renovated in 2014.

Metu is the capital town of the Illuababora zone in Oromia regional state. The source of raw water is Sore River and slow sand filter was used for treatment. The treatment plant consists of the sedimentation chamber (5.10 m x 26.50 m), aeration chamber (2.15 m x 5.10 m), two compartments of filtration tank (7.8 m x 13.30 m) each with a sand depth of 2 meters and a chlorination chamber. It served the town for about 32 years and conventional water treatment was under construction on the same source. Agro town has been served by ground water exploration from four bore holes situated in the west part of the town; while water is pumped to the reservoir for chlorination before distribution.

These towns were selected due to availability of the common conventional water treatment methods existing in Ethiopia (Rapid sand filter, slow sand filter and Borehole). Based on the Central Statistical Agency of Ethiopia (CSA) projection, the total population for Agaro, Jimma and Metu were 32, 928, 184, 925 and 37, 227 respectively [11].

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**Fig. 1** Map of the study area and sampling locations in Jimma, Agaro and Metu town, Southwest Ethiopia, 2016

## 2.2 Sample Collection

During the dry and rainy seasons, 84 representative samples were collected from the raw, filtered and treated water. Water samples were taken four times from each sampling locations during the rainy and dry seasons at 08:00-12:00 AM in 2014 and 2015. The sampling was carried out scrupulously following standard methods [12]. The water samples were collected aseptically using a sterile two liter polyethylene (PET) bottle for physicochemical analysis and 250 milliliter (mL) sterilized glass bottles for bacteriological analysis. Glass bottles were autoclaved with 0.1ml sodium thiosulphate for chlorinated water sample collection [13].

The tap was turned on at maximum flow rate and the water allowed to flow for 2 minutes. The tap was disinfected for a minute using a 70% alcohol and allowed to flow at a medium rate for 2 minutes. A previously sterilized glass and clean PET bottles were opened for collecting water samples by holding the bottle steady under the water jet, while the cover cup was held in up down position. Samples at treatment units were taken according to surface water sampling procedure by dipping the sampling container to 20 cm of the water body. The samples were sealed, labeled and transported in the icebox to Environmental Health Science and Technology Laboratory, Jimma University within 8 hours of sample collection (Table 1).

**Table 1** Water sample labels and details of sampling locations in Agaro, Jimma and Metu town, Southwest Ethiopia, 2016

S.No	Sample labels	Latitude	Longitude	Source
1	ATJ-1	37-232886	08-68842	Borehole
2	ATJ-2	37-0232530	8-68492	Borehole
3	ATJ-4	37-0232227	8-69942	Borehole
4	ATW1	37-0233665	8-68928	Tap water
5	ATW2	36-34'518	7-51295	Tap water
6	ATW3	36-35'265	7-51291	Tap water
7	ATW4	36-35'470	7-51158	Tap water
8	JRW	36,52,27.9	7-39099	Raw water
9	JSW	36-52396	7-39324	Settled water
10	JFW	36-52,279	7-39096	Filtered water
11	JCIW	36-52395	7-39324	Chlorinated water
12	JTW1	36-51181	7-40198	Tap water
13	JTW2	36-49'473	7-40101	Tap water
14	JTW3	36-49'520	7-40503	Tap water
15	JTW4	36-50'263	7-40444	Tap water
16	MRW	36-0786211	9-19163	Raw water
17	MFW	36-0786214	9-19165	Filtered water
18	MCIW	36-0786216	9-19167	Chlorinated water
19	MTW1	35-34'29.92	8-174818	Tap water
20	MTW2	35-33'29.70	8-191090	Tap water
21	MTW3	35-34'53.7	8-80832	Tap water

Physicochemical analysis: temperature, electrical conductivity (EC), dissolved oxygen (DO) and pH were determined using a pre-tested and a calibrated portable digital multi-parameter probe, specifically; Hatch PHC 101 probe, Hatch Loo, US PAT 691 2050 probe and Hatch CDC 401 probe, respectively. Similarly, turbidity was determined by Hanna LP turbidity meter [14]. Total alkalinity (TA) was determined by a visual titration method using methyl orange and phenolphthalein indicator. Total hardness (TH) was measured by ethylene-diaminetetra-acetic acid (EDTA)

titration method using Eriochrome black T (EBT) indicator according to standard methods [12]. Fluoride (F) was determined by Alizarin photometric method and [15] fluoride ion selective electrode for double checking. Nitrate (NO<sub>3</sub>) was measured using DR 5000; HACH, LANGE spectrophotometer and Iron (Fe) was determined by phenanthroline method. Free residual chlorine and Total residual chlorine were determined by the planitest diethyl paraphenylene diamine (DPD) method.

Bacteriological analysis: total coliform (TC) and fecal coliform (FC) were determined using membrane filtration (MF) technique within 8 hours of sample collection. Hundred mil-liters of water samples were filtered through 0.45 µm membrane filter, under vacuum. The membrane filter, then layered to 2 mL prepared (35.6 mg/L proportion) membrane lauryl sulfate broth (AVONCHEM, Limited) with absorbent pad and incubated at 37 °C and 44 (±0.5 °C) for 24 hours, respectively. After 24 hours of incubation, the plates were examined for development of yellow colonies and it was expressed in colony forming unit (CFU) per 100 mL of water sample [16]. Laboratory grade reagents and blank test were used for laboratory analysis and quality checking.

## 2.3 Water Quality Index (WQI)

A water quality Index is a numeric expression used to evaluate the quality of water and to be easily understood by managers. It is defined as a rating that reflects the composite influence of different water quality parameters [17]. It was calculated for drinking water in all towns. First, each of the parameters was assigned a weight (wi) based on their perceived effects on primary health. The highest weight of five was assigned to parameters which have the major effects on water quality. The relative weight (Wi) is computed from the following equation:

$$Wi = \frac{wi}{\sum_{i=1}^n wi} \quad (1)$$

where: Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters,  $\sum wi$  is the sum of all the parameters. Then, a quality rating scale (qi) for each parameter is assigned by dividing its concentration in each water sample by its respective standard and the result multiplied by 100,

$$qi = \frac{Ci}{Si} * 100 \quad (2)$$

where; qi is the quality rating scale, Ci is the concentration of each parameter in each water sample in mg/L, and Si is the World Health Organization standard for each parameter in milligrams per liter [18]. To calculate WQI, first, Si value were determined using the following equations:

$$Sii = wiqi \quad (3)$$

$$WQI = \sum Sii \quad (4)$$

The computed WQI values are classified into five categories as follows [19] <50: excellent water; 50–100: good water; 100–200: poor water; 200–300: very poor water; >300: unsuitable for drinking

Statistical Analysis: Microsoft Excel software analyze was deployed to determine drinking water quality compliance with the WHO guideline values and WQI calculation. The overall efficiency of the plants was calculated using the Log Removal value (LRV) and overall parametric efficiency (Eq.(5)) [20].

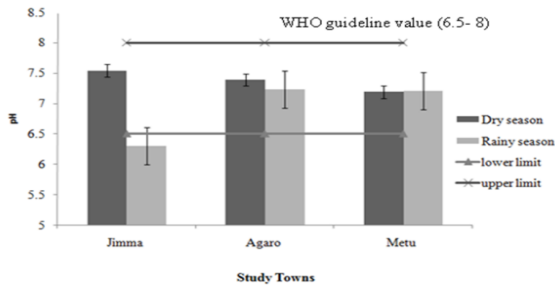
$$LRV = \log_{10} \left( \frac{\text{Influent concentration of contaminant}}{\text{Effluent concentration of contaminant}} \right) \quad (5)$$

## 3. Results and Discussion

### 3.1 pH

The majority (87.3%) of water sources pH were found within the recommended limits of WHO drinking water guideline values of 6.5 to 8 in both seasons [21] (Table 2 and Fig. 2). It was consistent with other studies done in Ethiopia [22, 23].

However, the lowest pH was 6.3±0.22 in Jimma water source during the rainy seasons. This may be due to the use of chemical alum (Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>) to coagulation process, in conventional treatment method as reported in another study in Nigeria [24] addition of excess aluminum sulfate would reduce the pH of the water. The pH values more than 8 are not suitable for effective disinfection with chlorine while values less than 6.5 enhance corrosion in water pipes and household plumbing systems [21].



**Fig. 2** Comparison of mean values of pH of drinking water sources during the dry and rainy seasons in Jimma, Agaro and Metu towns, Southwest Ethiopia, 2016

**Table 2** Drinking water quality compliance with the WHO permissible limits in the dry and rainy seasons in Jimma, Agaro and Metu town, Southwest Ethiopia 2016

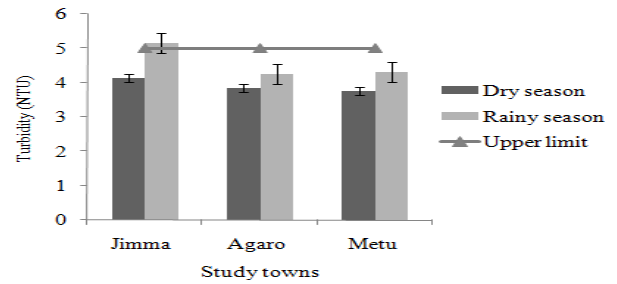
Parameters	Jimma town		Agaro town		Metu town		WHO limit
	Dry	Rainy	Dry	Rainy	Dry	Rainy	
Temperature	23.82 ±0.5	20.76 ±0.9	26.52 ±1.43	22.41 ±1.25	24.44 ±.95	22.00 ±1.06	25-30
pH	7.54 ±0.19	6.3 ±0.22	7.39 ±0.2	7.23 ±0.19	7.19 ±0.24	7.21 ±0.14	6.5-8
Turbidity	4.13 ±0.85	5.15 ±1.46	3.84 ±0.82	4.25 ±0.35	3.75 ±.34	4.30 ±0.47	5.0
Dissolved oxygen	6.74 ±0.46	7.50 ±0.56	5.34 ±2.26	5.7 ±1.74	6.22 ±1.32	7.56 ±0.64	6.0
Conductivity	182 ±5.99	105.8 ±1.2	635.4 ±11.7	624.1 ±12.8	261.0 ±5.4	264.5 ±10.2	1000
Total hardness	50.2 ±1.1	24.36 ±1.04	121.0 ±52.1	141.4 ±16.6	63.00 ±10.3	64.00 ±10.8	100
Total alkalinity	16.3 ±8.86	16.20 ±8.96	142.0 ±21.89	121.4 ±3.58	60.00 ±17.2	54.00 ±17.9	200
Nitrate	0.85 ±0.11	0.85 ±0.1	0.0 ±0.0	0.0 ±0.0	0.36 ±0.27	0.51 ±0.2	50
Iron	0.11 ±0.01	0.76 ±0.6	0.17 ±0.19	0.21 ±0.28	0.79 ±0.25	0.52 ±0.24	0.3
Fluoride	0.15 ±0.06	0.15 ±0.06	3.33 ±3.24	3.44 ±2.96	0.06 ±0.06	0.05 ±0.08	1.5
Total coliform	2.5 ±1.89	56 ±17.35	26.8 ±15.6	41.5 ±24.15	16.83 ±21.1	31.67 ±29.2	0
Faecal Coliform	0 ±0	3.25 ±3.9	5.75 ±2.6	10.5 ±5.92	1.17± 2.02	1.0 ±1.73	0

NB: Temperature measurements are in (°C), Dissolved oxygen, Total hardness, Total alkalinity, Iron, Nitrate, Fluoride in mg/L, Conductivity in (µS/cm), and Turbidity in (NTU), WHO limit= World Health Organization drinking water permissible standard

### 3.2 Turbidity

Turbidity is a very critical and widely used water quality physical parameter that can provide the most important data throughout out the water treatment process. The mean value of turbidity was found in the range between  $3.75 \pm 0.34$  to  $5.15 \pm 1.46$  in the treated water (Fig. 3). The highest turbidity was observed in Jimma town water source in the rainy season and the lowest was in Metu town water source during the dry season (Table 2). This finding was consistent with the study reported in Bahir Dar city [25]. But, it varies with the previous Ethiopian drinking water rapid assessment reported that turbidity was a major water quality problem due to poor sanitary conditions of water supplies in almost all parts of Ethiopia [9]. Turbidity of 0.5 NTU is recommended for effective disinfection in drinking water treatment. However, up to 5 NTU is considered acceptable to the consumers [21]. The slight increment of turbidity observed in Jimma during the rainy season may be due to high runoff from the Gilgel Gibe River causes much agitation and mixture of debris in the water and technical incompetence of water treatment personnel as reported in another study in Nigeria [24]. Turbidity of water affects treatment processes with chlorine and reduces the pathogen removal [26]. Therefore, further investigation is required to identify the reasons for turbidity rainy season maxima to achieve effective disinfection for pathogen removal and tailored strategy may require responding to the change.

The log removal value (LRV) and efficiency of water treatment plants were 1.28 and 94.8%, 1.08 and 91.69% for turbidity, in Jimma and Metu town, respectively (Table 3). Jimma and Metu town water treatment plants were efficient for the removal of turbidity as compared to a study in Nigeria [27]. In Agaro the turbidity of raw and treated water was almost similar, due to less suspended solids in ground water. However, the LRV and overall efficiency of Jimma conventional water treatment plant for iron removal was lower than the previous study [24].



**Fig. 3** Turbidity of drinking water sources during dry and rainy seasons in Agaro, Jimma and Metu towns, Southwest Ethiopia, 2016

### 3.3 Electrical Conductivity (EC)

Agaro town ground water source was the highest in EC ( $635.4 \pm 11.7$  µS/cm). This may be due to high concentration of dissolved ions in contact with the aquifer in ground water sources [28]. Previous studies also reported a similar finding of EC on ground water sources in Ethiopia [9] and Turkey [29].

It was observed that, the level of EC increases from raw water to final in the surface water source of Jimma town (Table 4). The increments of EC were attributed to the addition of coagulants for turbidity removal and chlorine-based chemicals for disinfection purpose. These chemicals became dissolved solids in the water and thereby increased the EC of the water; the higher the dissolved solids in the water, the higher its EC and it increased from raw to treated water. Although, EC of all water sources in the study area was found below the WHO drinking water permissible limits of 1000 µS/cm [18].

### 3.4 Total Hardness

The minimum value of TH was  $24.36 \pm 1.04$  mg/L in Jimma water source and the maximum was  $141.4 \pm 16.6$  mg/L in Agaro water source (Table 2). The hardness category of water sources was soft, moderately hard and hard in Jimma, Metu and Agaro towns, respectively [22]. Hardness is one of the very important properties of ground water from a utility point of view. Even though, there is no health based guideline value, the community may be wasting money for soap consumption and suffering from the effects of scale deposition in distribution systems and water boiling materials which consume much fuel and causes taste problems. Public acceptability of the degree of hardness may vary considerably from one community to another. However, hardness value above 500 mg/L is generally unacceptable [30].

### 3.5 Fluoride (F)

The highest concentration of fluoride was found in Agaro town ground water source ( $3.33 \pm 3.24$  and  $3.44 \pm 2.96$  mg/L) in the dry and rainy seasons, respectively. Whereas, in Jimma and Metu town water sources, it was below the recommended WHO guideline values of 1.5 mg/L [18] (Table 2). Borehole (ATJ-4) contains the highest amount of fluoride (10.03 mg/L), which is responsible for the excess fluoride concentration in the town water supply. This finding is consistent with the study done in the rift valley areas of Ethiopia, which was 11.6 mg/L in ground water sources [31]. The other study conducted in the Rift Valley area, fluoride concentration was found above 5.0 mg/L in shallow wells and boreholes; the river and spring sites had levels below 1.5 mg/L [32]. This finding showed that, the fluoride concentration in the Agaro town water source was even higher than some part of Rift Valley area ground water sources. Therefore, urgent measures should be taken by the water authority before the community exposed to high risk of dental fluorosis like rift valley areas of Ethiopia.

### 3.6 Iron

Iron concentration in the Metu water source was  $0.79 \pm 0.25$  and  $0.52 \pm 0.24$  in the dry and rainy seasons; which is beyond the WHO recommended limits of 0.3 mg/L [18]. The possible reason for high iron content in Metu water sources would be the infiltration of adjacent ground water with iron content of 3 mg/L. People using water sources with high concentration of iron were suffering from taste, color, corrosion of plumbing systems and liver diseases; however, those exposed to less concentration would be highly susceptible to anemia as cited in [33]. The log removal value and efficiency of treatment plants was found to be 0.19 and 34.91% respectively (Table 3). The efficiency was nearly two-third times lower than the previous study in Nigeria [24]. The possible reason could be the efficiency of slow sand filter treatment system may not be comparable with the conventional one.

### 3.7 Bacteriological Quality

The study revealed that, both TC and FC in all town water sources were above the recommended limits of WHO drinking water guideline values (0/100 mL) in the rainy season (Fig. 4-6). This may be due to high runoff, rising of the water table, leaching during the rainy season and failure of the treatment plant [34]. However, the FC count of Jimma town water source was within the WHO limit in the dry season. The possible reason may be the treatment process during the rainy season could be affected by turbidity of surface water sources due to high rainfall.

In Agaro ground water source up to 16.11 and 7.33 CFU/100 mL FC was detected in raw and treated water samples, respectively. The high FC count may be attributed to the failure of the treatment process due to malfunctioning of automatic chlorination devices and manual application of chlorine [35]. In addition, free residual chlorine was not detected in Agaro town water source throughout the study periods (Fig. 5). According to the WHO guideline, for inactivating 90% of FC a free chlorine residual of 1 mg/L is required for about 25–30 minutes. The residual chlorine in Jimma and Metu water sources was found in the recommended limits (0.5 mg/L) in the dry season [18]. Lack of regular water quality monitoring in the treatment plant and distribution may be the possible explanation for the poor bacteriological quality of water sources in the study area. A study done in Pakistan also indicated that water treatments with nonfunctional chlorination equipment had more TC and FC in the distribution system [35]. This finding also consistent with the previous studies conducted in the Jimma zone on spring water and hand dug well bacterial loads of non-chlorinated water sources [8, 10].

The LRV and efficiency of treatment plants were 1.27 and 94.6%, 0.34 and 54.5% and 1.35 and 95.5% for FC in Jimma, Agaro and Metu town, respectively. The FC removal efficiency of Jimma and Metu water treatments were in line with the water research Australia recommendations of LRV of 1,2 and 3 is equivalent to 90%, 99% and 99.9%, respectively, for target pathogen removal [20]. Agaro ground water treatment efficiency was lower than other studies; This may be due to malfunctioning of chlorination devices and manual application of chlorine affects the bacteriological quality. Even though, lack of previous study in Ethiopia, the treatment efficiency was slightly lower than a study done in Nigeria [24] and report of Jefferson City rapid sand filter treatment plant efficiency [36].

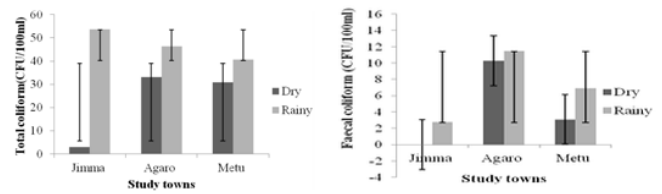


Fig. 4 Total coliform and Faecal coliform in water sources during dry and rainy seasons in Jimma, Agaro and Metu towns, southwest Ethiopia, 2016

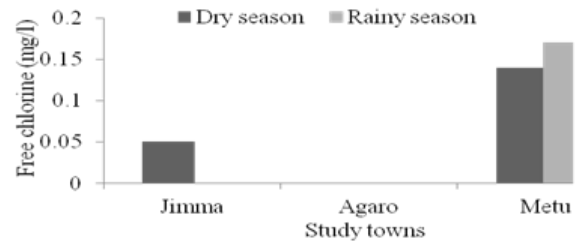


Fig. 5 Free residual chlorine in water sources during dry and rainy seasons in Jimma, Agaro and Metu towns, southwest Ethiopia, 2016

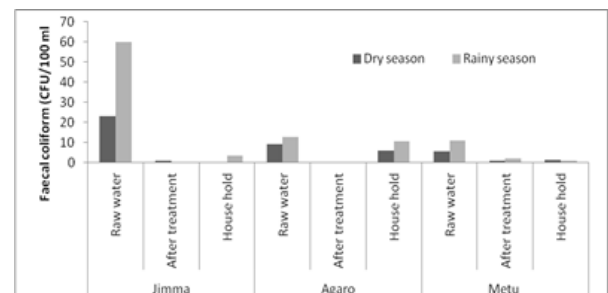


Fig. 6 Faecal coliform count at sampling points of Jimma, Agaro and Metu town, Southwest Ethiopia, 2016

Table 3 Overall Efficiency of the treatment processes on selected parameters considered, in Jimma, Agaro and Metu towns, Southwest Ethiopia, 2016

Water Parameters	Jimma water treatment (Rapid sand filter)				Agaro water treatment (only Chlorination)				Metu water treatment (slow sand filter)			
	Raw	Treated	LRV	%	Raw	Treated	LRV	%	Raw	Treated	LRV	%
Turbidity	88.9	4.62	1.28	94.8	4.09	3.89	0.02	4.89	48.97	4.07	1.08	91.69
Electrical Conductivity	131	160.4	-0.09	-	625.3	636.4	-0.01	-	261	261.17	0.00	-
Iron	0.97	0.55	0.25	43.3	0.28	0.11	0.41	60.7	1.06	0.69	0.19	34.91
Faecal coliform	35.5	1.92	1.27	94.6	16.11	7.33	0.34	54.5	40.67	1.83	1.35	95.50
Total coliform	100	38.42	0.42	61.6	45.33	31.67	0.16	30.1	100	25.75	0.59	74.25
Average % effectiveness	73.6								48.4			

NB. Turbidity (NTU), Iron (mg/L), Total and Faecal coliform (CFU/100 mL), LRV= Log Removal Value, %= efficiency percent

Table 4 Physiochemical parameters considered to calculate the drinking water quality index, Southwest Ethiopia, 2016

Parameters	WHO standard	Jimma			Agaro			Metu		
		Ci	wi	Wi	Ci	wi	Wi	Ci	wi	Wi
pH	6.5	7.12	4	0.1176	7.35	4	0.1176	7.28	4	0.118
Turbidity	5	4.62	5	0.1471	3.89	5	0.1471	4.07	5	0.147
Dissolved O <sub>2</sub>	6	6.75	4	0.1176	6.82	4	0.1176	6.75	4	0.118
Conductivity	1000	160.14	5	0.1471	636.42	5	0.1471	261.17	5	0.147
Total hardness	100	41.18	3	0.0882	106.25	3	0.0882	64.33	3	0.088
Nitrate	50	0.89	5	0.1471	0	5	0.1471	0.48	5	0.147
Iron	0.3	0.55	3	0.6000	0.11	3	0.0882	0.69	3	0.088
Fluoride	1.5	0.15	5	0.1471	3.12	5	0.1471	0.05	5	0.147
		∑wi =34			∑wi =34			∑wi =34		

Note: Ci= concentration in mg/L, wi= weight, Wi= relative weight

### 3.8 Water Quality Index Calculation

WQI is an important parameter for identifying the water quality and its suitability for drinking purposes [17]. In the present study, WQI was computed for the three town water supplies. First, important water quality parameters (pH, Turbidity, DO, EC, Total hardness, Nitrate, Iron and Fluoride) were selected and a weight was assigned to each parameter depending upon the effect on human health and water quality. In addition, the limit values of the World Health Organization's guidelines [21] were utilized in the calculations (Table 4). The highest weight of 5 was assigned to parameters such as Turbidity, EC, Nitrate and fluoride, which have the major effects on drinking water quality. While, DO and pH has been assigned a weight of 4; Hardness and Iron have been assigned a value of 3 by taking into consideration their importance in water quality. The relative weights (Wi) are computed for each parameter and results are

given in Table 4. The WQI values have been calculated using related equations (Eqs.(1-4)) given in the method part and WQI results and water classification for all towns were presented in Fig. 7. The WQI for these town water supplies were ranged from 68.78 in Metu and 157.4 in Jimma town. The classification was "good water" in Metu and Agaro water supplies, whereas Jimma town water supply was classified in "Poor water" category. The water quality in the study area was in good and poor category as compared to a study done in Nepal [17]. The possible reason may be water treatment plant efficiency was not controlled in the rainy season due to high runoff from Gilgel Gibie River and high fluoride concentration in the Agaro water source. From the LRV and WQI calculation, the researcher concluded that, the quality of drinking water in the study area needs attention for quality checking and deployment of skilled personnel for proper operation the treatment plants.

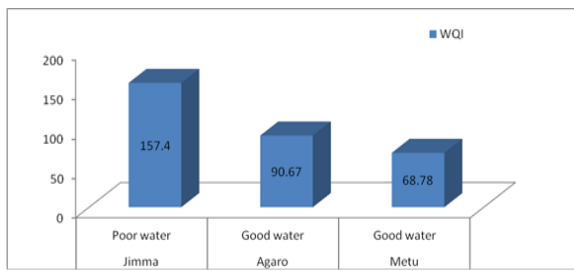


Fig. 7 Water quality index, in Jimma, Agaro and Metu town, Southwest Ethiopia, 2016

#### 4. Conclusion

Physicochemical quality of all water sources was in compliance with the WHO recommended limits. TC and FC were identified in both water sources indicated lack of regular sanitary checking and skill gaps in chlorination process. Free residual chlorine was very minimal and below detectable limits in treated water samples and needs strict monitoring and regular checkup for removal of bacteriological indicator bacteria.

Fluoride concentration in the borehole (ATJ-4) was 10.03 mg/L and the tap water samples were 3.12 mg/L which is higher than the recommended limits. ATJ-4 may be the source of high fluoride in Agaro town. Therefore, looking alternative source or treatment of the sources is a solution to avoid high fluoride concentration problems.

The WQI showed that, the Jimma water was classified as poor, and Agaro and Metu were in the good category. Therefore, WSA needs strict evaluation of the water quality in the rainy season, particularly in Jimma and Agaro towns. The overall efficiency of treatment plants were 73.6%, 48.4% and 74.1% effective in overall pollutant removal in Jimma, Agaro and Metu town, respectively. The study concluded that the treatment plants were still technologically appropriate to deliver safe water to the public, but giving attention on technical skills on water quality monitoring may improve the observed negative findings on bacteriological quality and free residual chlorine.

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