Analyzing Seasonal Change of Water Quality Characteristics of Finote Selam Town Drinking Water Sources, Amhara, Ethiopia

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Abstract. Water quality is used to demonstrate chemical, physical and biological characteristic of water. It has a significant impact on human's day to day activity. Even if it has such prominence, its quality is not constant with time and known as a media for disease transmission in the globe. In Ethiopia, there is a shortage of information in seasonal variation of water quality characteristics of drinking water sources. Thus, a cross-sectional study was undertaken to analyze water quality characteristics of drinking water sources in Finote Selam. A total of 32 water samples were collected from four drinking water sources and used to analyze turbidity, EC, TDS, NO_3, TC, FC, Ca, Mg, PO_4, PH, Fe, NH_3 and temperature. From a total of 16 water samples tested for water quality parameters in each season, some of the parameters were above the WHO standard in the dry and wet season. For turbidity 2 (12.5%), EC 16 (100%), TC 16 (100%), PO4 3 (18.75%) and FC 12 (75%) were above WHO standard in the dry season whereas for turbidity 11 (68.75%), EC 14 (87.5%), TC 16 (100%), PO4 6 (37.5%), Mg 2 (12.5%) and FC 16 (100%) were above WHO standard in the wet season. For PH 11 (68.75%) and 12 (75%) water samples were below WHO standard in the dry and wet season respectively. The research result indicated that the quality of water sources were not safe in dry and wet season since majority of the samples taken were not meet WHO standard. So, it is desirable to monitor and manage drinking water sources.

Keywords: Water quality · Water sources · Water quality characteristics · Finote selam town

1 Introduction

Water is most important and plentiful resource on earth. It is crucial for the survival of every organism [9]. Humans can survive more than weeks without food on the other hand only just few days without water. It has also an equivalent importance with the air we inhale in sustaining the vital processes of life. It is an important constituent for life and used for several purposes by man [2].

Water quality is the chemical, physical and biological characteristic of water. These characteristics are influenced by both natural processes and human activities. It changes

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from place to place with season, climate and the types of soil and rocks over which water moves [12]. A variety of human activities like industrial, mining, agriculture, urban expansion and recreation greatly transform the quality of natural water and alter the water use possibly [6]. All of these natural processes and human actions alter the quality and potentiality of the natural water [4].

Springs are unconstrained aquifers where flow of water is under gravity [13]. They occur where sloping ground and impermeable strata traverse with the ground water table. They became polluted as a result of poor site selection, protection and unhygienic management [14].

Groundwater is the world's biggest and most significant source of fresh potable water [11]. It is considered as safe source of drinking water. Nevertheless, ground water resources are susceptible to contamination. This is due to naturally occurring pollutants existing in the rocks and sediments [10]. Like surface water, its quality is different from place to place reliant on seasonal changes [5]. It is also altered based on the types of soils, rocks and surfaces over which it moves [12].

In addition, human activities can change natural composition of groundwater in spreading of chemicals and microbial matter on land surface and into soils through inoculation of wastes directly into groundwater. Industrial by products which are discharged from dissimilar factories in comprising various chemicals are the causes for the natural composition of groundwater alteration [3]. Agricultural and urban activities are other reasons for groundwater quality alteration [7]. Inappropriate supervision of both solid and liquid waste including disposal of waste can influence groundwater quality [1]. Urbanization is also gradually taking along the problems of contamination because of increased poor waste management and inadequate sanitation systems. Thus, influencing both the physical, chemical and microbial quality of water [10].

Water is a well-familiar transmission medium for communicable diseases all over the world. In Ethiopia, Seasonal change of water quality is not well understood and slight care is given. There is no study done concerning seasonal change of physico-chemical and bacteriological quality of drinking water sources for Finote selam town. So, the current study is designed to evaluate the seasonal changes of physicochemical and bacteriological quality of drinking water sources in Finote selam town.

2 Materials and Methods

2.1 Study Area

The study was conducted in Finote selam town which is the capital city of West Gojam zone. It is located 387 km from Addis Ababa and 176 km from Bahir Dar. It has a longitude of 37° 16' E from the Greenwich meridian and 10° 42'N latitude from the equator with an elevation of 1917 m above mean sea level. According to the national population and housing census, the total population statistics of Finote selam town was 25,913. From this, 50.3% were men and 49.7% were women [8].

2.2 Study Design

A cross-sectional study design was conducted to evaluate the seasonal change of water quality parameters of drinking water sources in Finote selam town from January 2012 to October 2013. Membrane filtration and palintest photometer techniques were used for bacteriological and chemical water quality parameter analysis respectively.

2.3 Sample Size and Sample Collection

Four water sources were used for sample collection. They were designated as ws_1, ws_2, ws_3 and ws_4. A total of 32 water samples from these water sources were collected. That is, four water samples in the dry season and four water samples in the wet season.

Sample collection in dry season was carried out in January, February, March and April 2012. For wet season, samples were collected in June, July, August 2012 and September 2013. Water samples were collected using sterilized 2-L plastic containers. These containers were rinsed with sample at the sites of sample collection before samples were collected.

All samples were collected between 9:00 am to 12:00 am and transported to Finote selam town water supply and sewerage office laboratory in ice box and processed within 6 h after sample collection. The collected samples were analyzed for turbidity, electrical conductivity, temperature, PH, total dissolved solid, nitrate, ammonia, calcium, magnesium, phosphate, iron, total coli form and f-coli form.

2.4 Physicochemical Analysis

The study was carried out by analyzing some of the parameters on field and the others in the laboratory. The selected parameters analyzed in the field were temperature, pH, total dissolved solids, electrical conductivity and turbidity. These parameters were tested using the Palin test- multi-parameter and turbidity meter respectively (UK). The parameters analyzed in the laboratory were nitrate, ammonia, calcium, magnesium, phosphate and iron. These parameters were tested using the Palin test- photometer method (palintest-photometer 7500 Bluetoth, UK).

2.5 Microbiological Analysis

Total and faecal coliforms were analyzed by following palintest membrane filtration method. The media was prepared based on the manufacturer's instruction.Filtration unit was loosened and disinfected with methanol alcohol. A covered membrane filter was removed and transparent outer protection was peeled with forceps. The membrane filter was placed on the bronze filter support disc housed in the blue rubber base and then, filter funnel was locked firmly by pushing into the blue rubber base.Filter funnel base assembly was inserted into sampling cup and water sample was poured to the filter funnel up to 100 ml graduation. A hand vacuum pump was connected to filtration unit and pumping was begun. When all of the sample has been filtered, vacuum pump was detached and filter funnel was removed from blue rubber base. Petri dishes were placed on to the working - surface and sterilized with ethanol. After cooling, the absorbent pad was added by spinning. Then, media measuring device containing the liquid lorine sulphate broth media was shaked and then, the blue screw lid removed and placed lid-down on to the work-surface. Finally, the media was poured onto absorbent pad in petri dish. Sterilized forceps was used to lift membrane filter from the filtration in blue rubber base and was placed on top of the absorbent pad. Petri dish lid was replaced, labeled with sampling place and placed on to the petri dish rack. Then, petri dish was incubated at 37° for 18 h for total coliform and at 44 °C for 18 h for faecal coliform.

2.6 Data Analysis

The data obtained from field and in laboratory were analyzed using one way anova in SPSS software for windows version 21. One way anova was used to check whether there is a statistically significant difference or not among the water sources. The level of confidence interval was set as 95%.The results of the selected water quality parameters were compared with water quality standards set by [15].

3 Results and Discussion

In this research, a total of 32 water samples were collected from four water sources (two deep wells and two developed springs). Eight water samples were taken from each drinking water source.Water quality parameters of drinking water sources were compared with a global water quality standard [15].

Table 1. Analysis of variance for water quality parameters of water sources in dry season

Water quality parameters	Drinking water sources				P-value
	WS_1	WS_2	WS_3	WS_4	
Turb (NTU)	4.1 ± 0.6	5.9 ± 4.4	0.7 ± 0.1	3.0 ± 1.2	0.04
EC (μscm^{-1})	365.7 ± 59.2	637.7 ± 44.2	542.3 ± 43.2	540.2 ± 152.5	0.02
Temp (°C)	23.2 ± 0.83	25.9 ± 2	25.0 ± 0.6	22.9 ± 0.9	0.01
PH	5.4 ± 1.0	6.5 ± 0.6	6.06 ± 0.8	5.4 ± 1.0	0.24
TDS (mgL^{-1})	201.2 ± 37.6	350.7 ± 28.1	298.3 ± 27.4	297.1 ± 96.9	0.02
NO3 (mgL^{-1})	2.1 ± 0.1	1.6 ± 0.3	1.4 ± 0.2	3.1 ± 0.1	0.00
NH3 (mgL^{-1})	0.2 ± 0.0	0.2 ± 0.1	0.2 ± 0.0	0.2 ± 0.1	0.84
TC (CFU)	6.3 ± 4.2	3.5 ± 1.3	11.0 ± 5.4	10.00 ± 2.9	0.05
FC (CFU)	0.8 ± 1.0	0.5 ± 0.58	1.8 ± 0.1	3.0 ± 0.8	0.01
Ca (mgL^{-1})	8 ± 2.7	10.8± 3.8	17.0 ± 2.6	28.5 ± 5.2	0.00
Mg (mgL^{-1})	16 ± 2.7	21.3 ± 3	27.3 ± 3.0	27.8 ± 5.4	0.00
PO4 (mgL^{-1})	0.2 ± 0.0	0.4 ± 0.2	0.4 ± 0.1	0.6 ± 0.2	0.02
Fe (mgL^{-1})	0.1 ± 0.0	0.03 ± 0.01	0.1 ± 0.0	0.04 ± 0.0	0.00

Table 2. Analysis of variance for water quality parameters of water sources in wet season

Water quality parameters	Drinking water sources				P- value
	WS_1	WS_2	WS_3	WS_4	
Turb (NTU)	10.9 ± 5.4	7.7 ± 4.4	3.4 ± 0.9	15.2 ± 4.9	0.01
EC (μscm^{-1})	580.9 ± 177.6	502.6 ± 172.5	455.8 ± 141.2	616.3 ± 135.5	0.49
Temp (°C)	20.1 ± 1.6	21.0 ± 0.5	20.0 ± 2.1	20.7± 1.7	0.8
PH	6.5 ± 0.4	5.9 ± 0.7	5.4 ± 0.9	5.7 ± 0.9	0.21
TDS (mgL^{-1})	319.47 ± 97.7	276.4 ± 94.9	250.7± 77.6	338.9 ± 74.5	0.49
NO3 (mgL^{-1})	2.8 ± 0.4	2.09 ± 0.4	2.05 ± 0.2	3.2 ± 0.9	0.04
NH3 (mgL^{-1})	0.4 ± 0.2	0.3 ± 0.2	0.2 ± 0.1	0.1 ± 0.0	0.02
TC (CFU)	71.5 ± 37.3	36.3 ± 7.8	87.8 ± 33.6	115.3 ± 23.2	0.01
FC (CFU)	39.3 ± 11.2	16.0 ± 10.6	25.5 ± 10.1	57.0 ± 33.4	0.05
Ca (mgL^{-1})	11.8 ± 1.3	67.5 ± 7.2	20.0 ± 5.9	23.8 ± 9.5	0.13
Mg (mgL^{-1})	32.5 ± 7.2	32.0 ± 3.6	37.0 ± 9.3	52.0 ± 8.0	0.01
PO4 (mgL^{-1})	0.4 ± 0.2	0.4 ± 0.2	0.4 ± 0.1	0.7 ± 0.3	0.12
Fe (mgL^{-1})	0.2 ± 0.1	0.1 ± 0.0	0.1 ± 0.1	0.2 ± 0.1	0.68

Table 3. Compliance of drinking water sources in the dry season

Parameters		Ws_1		Ws_2		Ws_3		Ws_4		Total sample	
	WHO	N	P	N	P	N	P	N	P	N	P
Turb (NTU)	>5	0	0	2	50	0	0	0	0	2	12.5
	<5	4	100	2	50	4	100	4	100	12	87.5
EC (μscm^{-1})	>300	4	100	4	100	4	100	4	100	16	100
	<300	0	0	0	0	0	0	0	0	0	0
Temp (°C)	>15	4	100	4	100	4	100	4	100	16	100
	<15	0	0	0	0	0	0	0	0	0	0
PH	>8.5	0	0	0	0	0	0	0	0	0	0
	6.5–85	1	25	2	50	2	50	0	0	5	31.25
	<6.5	3	75	2	50	2	50	4	100	11	68.75
TDS (mgL^{-1})	>100	0	0	0	0	0	0	0	0	0	0
	<100	4	100	4	100	4	100	4	100	16	100
NO3 (mgL^{-1})	>50	0	0	0	0	0	0	0	0	0	0
	<50	4	100	4	100	4	100	4	100	16	100
NH3 (mgL^{-1})	>1.5	0	0	0	0	0	0	0	0	0	0
	<1.5	4	100	4	100	4	100	4	100	16	100
Ca (mgL^{-1})	>75	0	0	0	0	0	0	0	0	0	0
	<75	4	100	4	100	4	100	4	100	16	100
Mg (mgL^{-1})	>50	0	0	0	0	0	0	0	0	0	0
	<50	4	100	4	100	4	100	4	100	16	100
PO4 (mgL^{-1})	>0.50	0	0	1	25	0	0	2	50	3	18.75
	<0.50	4	100	3	75	4	100	2	50	13	81.25
Fe (mgL^{-1})	>0.30	0	0	0	0	0	0	0	0	0	0
	<0.30	4	100	4	100	4	100	4	100	16	100
TC (CFU)	>0	4	100	4	100	4	100	4	100	16	100
	<0	0	0	0	0	0	0	0	0	0	0
FC (CFU)	>0	2	50	2	50	4	10	4	10	12	75
	<0	2	50	2	50	0	0	0	0	4	25

Table 4. Compliance of drinking water sources in the wet season

Parameters		Ws_1		Ws_2		Ws_3		Ws_4		Total sample	
	WHO	N	P	N	P	N	P	N	P	N	P
Turb (NTU)	>5	4	100	3	75	0	0	4	100	11	68.75
	<5	0	0	1	25	4	100	0	0	5	31.25
EC (μscm^{-1})	>300	4	100	3	75	3	100	4	100	14	87.5
	<300	0	0	1	25	1	25	0	0	2	12.5
Temp (°C)	>15	4	100	4	100	4	100	4	100	16	100
	<15	0	0	0	0	0	0	0	0	0	0
PH	>8.5	0	0	0	0	0	0	0	0	0	0
	6.5–8.5	3	75	1	25	0	0	0	0	4	25
	<6.5	1	25	3	75	4	100	4	100	12	75
TDS (mgL^{-1})	>100	0	0	0	0	0	0	0	0	0	0
	<100	4	100	4	100	4	100	4	100	16	100
NO3 (mgL^{-1})	>50	0	0	0	0	0	0	0	0	0	0
	<50	4	100	4	100	4	100	4	100	16	100
NH3 (mgL^{-1})	>1.5	0	0	0	0	0	0	0	0	0	0
	< 1.5	4	100	4	100	4	100	4	100	16	100
Ca (mgL^{-1})	>75	0	0	0	0	0	0	0	0	0	0
	<75	4	100	4	100	4	100	4	100	16	87.5
Mg (mgL^{-1})	>50	0	0	0	0	0	0	2	50	2	12.5
	<50	4	100	4	100	4	100	2	50	14	87.5
PO4 (mgL^{-1})	>0.50	2	50	1	25	0	0	3	75	6	37.5
	<0.50	2	50	3	75	4	100	1	25	10	62.5
Fe (mgL^{-1})	>0.30	0	0	0	0	0	0	0	0	0	0
	<0.30	4	100	4	100	4	100	4	100	16	100
TC (CFU)	>0	4	100	4	100	4	100	4	100	16	100
	<0	0	0	0	0	0	0	0	0	0	0
FC (CFU)	>0	4	100	4	100	4	100	4	100	16	100
	<0	0	0	0	0	0	0	0	0	0	0

Key: N = number of sample = percent, Turb = turbidity, temp = temperature, TC = total coliform, FC = feacal coliform

3.1 Physicochemical Quality of Drinking Water Sources

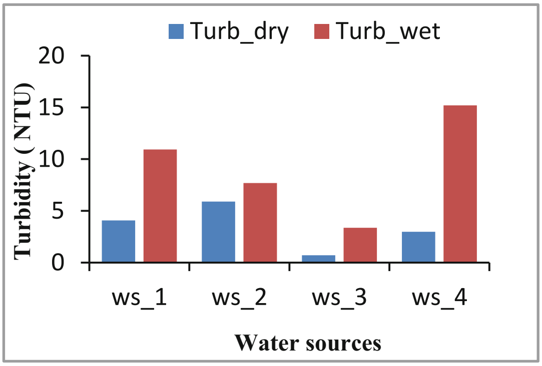

Fig. 1. Turbidity variation in season

Turbidity values ranged between 0.70 to 5.90 NTU in the dry season. A greater turbidity value of 5.90 NTU was noticed from ws_2. This was followed by ws_1 (4.07 NTU), ws_4 (2.98 NTU) and ws_3 with the lowest value of 0.70 NTU. In the wet season, results of turbidity fluctuated between 3.37 to 15.20 NTU. The values were gained in this decreasing order, ws_4 (15.20 NTU), ws_1 (10.94 NTU), ws_2 (7.69 NTU) and ws_3 (3.37 NTU). Turbidity values in this study were found higher in wet season than in the dry season across all the water sources (Fig. 1). This might be due to the entrance of run-off to the water sources that came from a nearby different anthropogenic activities. The reason for the greater difference between ws_3 and ws_4 was the variation in protection and geologic formation. A visible deviation between ws_1 and ws_2 is due to the difference in well characterstics.The result of one-way anova showed that there was a statistically significant difference in the mean turbidity values among the water sources in the dry and wet season ($p \leq 0.05$). Among 16 drinking water samples collected in the dry season from four water sources tested for turbidity, 14 (87.5%) were below the upper limit of WHO guideline value for turbidity <5 NTU but 2 (12.5%) were above WHO guideline value for turbidity >5 NTU (Table 3).This low level of compliance was observed as of water samples collected from ws_2. In the wet season, 11 (68.75%) water samples were above the limit value of WHO standard whereas only 5 (31.25%) of the water samples were in accordance with the limit value of WHO standard (Table 4). The low level of compliance was observed from water samples collected from ws_2. The lowest compliance was observed as of water samples collected from ws_1 and ws_4. The lowest compliance was observed as of water samples collected from ws_1 and ws_4.

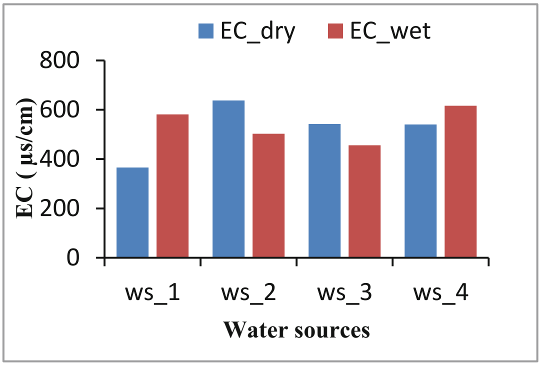

Fig. 2. EC variation in season

The electrical conductivity of the samples were found in the range of 365.72 μscm^{-1} to 637.66 μscm^{-1} in the dry season. Ws_2 was having the uppermost value of 637.66 μscm^{-1}. Next to it was ws_3 (542.32 μscm^{-1}), ws_4 (540.18 μscm^{-1}) and ws_1 (365.72 μscm^{-1}). The values varied between 455.29 μscm^{-1} to 616.25 μscm^{-1} in the wet season. Higher value of 616.25 μscm^{-1} was detected from ws_4. Subsequently, ws_1 (508.86 μscm^{-1}, ws_2 (502.61 μscm^{1}) and ws_3 (455.29 μscm^{-1}). Ws_4 and ws_1 showed higher EC values in the wet season and lower values in the dry season whereas Ws_2 and ws_3 revealed higher EC values in the dry season and lower values in the wet season (Fig. 2). The higher values of EC at ws_1 and ws_4 in wet season might be due to the entrance run-off which came from different human activities near the sources. The reasons for higher value of EC at ws_2 and ws_3 in the dry season might be due to the transformation of minerals to different ions from the rocks. As presented in Table 1, the results of one way anova showed that the spatial difference in EC was statistically significant in the dry season amongst the water sources. Contrary to this, there was no a significant difference in the means of EC amongst the water sources in the wet season (Table 2). For water samples tested from water sources in the dry and wet season, 16 (100%) and 14 (87.5%) were above the limit value of WHO standard (Table 3) while only none and 2 (12.5%) (Table 4) of the water samples were in accordance with the limit value of WHO standard respectively. The lowest compliance across all the water sources in the dry season might be due to the conversion of minerals to numerous ions from the host rocks.

The temperature of water samples analyzed altered between 22.93 °C to 25.85 °C in the dry season. Ws_2 recorded higher value of temperature 25.85 °C. This was followed by ws_3 with (24.95 °C), ws_1 (23.21 °C) and ws_4 with the lowermost value of (22.93 °C). In the wet season, the temperature readings ranged between (20.06 °C to 21.02 °C). Ws_2 was found to have the highest value of 21.02 °C, ws_4 (20.66 °C), ws_3 (20.08 °C) and ws_1 with lowest temperature of 20.06 °C. The values of temperature were found to be higher in the dry season across all the water sources. Based on one way anova carried out among the water sources in two different seasons, there was a significant difference among the means of all the water sources in the dry season ($P \leq 0.05$).However, there was no a significant difference in the means of the water sources in the wet season (Table 4).

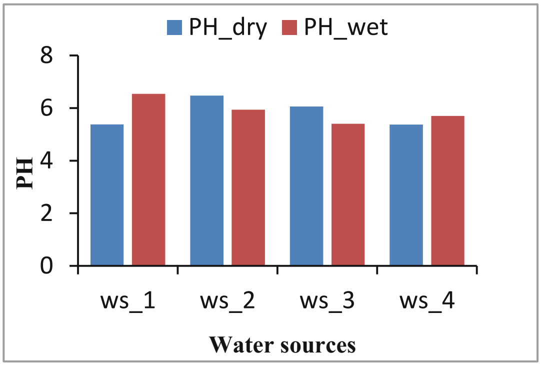

Fig. 3. PH variation in season

The values of pH found in this research ranged between 5.35 to 6.47 in the dry season. Upper pH values were recorded from ws_2 (6.47), ws_3 (6.06), ws_4 (5.37) and lower pH value in the dry season (5.35) was found from ws_1. During wet season, pH values varied between 5.40 to 6.54 with ws_1 having the highest value of 6.54, following it was ws_2 (5.94), ws_4 (5.70) and ws_3 with the lowest value of 5.40. Ws_1 and ws_4 indicated lower PH values in the dry season and higher PH values in the wet season.Ws_2 and ws_3 showed higher PH values in the dry season and lower values in the wet season (Fig. 3). The higher values from ws_1 and ws_4 in the wet season might be due to the infiltration of run-off from different human activities around the sources whereas the reasons for greater value in the dry season at ws_2 and ws_3 might be due to the release of different ions from the rocks. The spatial variation among the water sources in both the seasons remained insignificant ($p \geq 0.05$). From a total of 16 water samples collected in the dry season from four water sources, 11 (68.75%) water samples were below the lower bound of WHO standard (Table 3). The lower level of compliance from ws_3 and ws_4 might be due to the activity of bacteria during the decomposition of dead wood and plant leaves that has been fallen. In the same way, water samples collected in the wet season from water sources, 12 (75%) of the water samples were below the lower bound of WHO standard (Table 4).

The results of TDS was gained in the range of 201.15 mgL^{-1} to 350.71 mgL^{-1} in the dry season. Ws_2 had the higher value of 350.71 mgL^{-1}. This was followed by ws_3 (298.28 mgL^{-1}), ws_4 (297.10 mgL^{-1}) and the lowest value of ws_1 (201.15 mgL^{-1}). The result ranged from 250.68 mgL^{-1} to 338.94 mgL^{-1} in the wet season. Ws_4 had the uppermost value of 338.94 mgL^{-1}. Subsequently, ws_1 (319.47 mgL^{-1}), ws_2 (276.44 mgL^{-1}) and ws_3 had the lowermost values of 250.68 mgL^{-1}. Ws_1 and ws_4 revealed higher values of TDS in the wet season and lower values in the dry season where ws_2 and ws_3 showed higher values of TDS in the dry season and lower values in the wet season. The result of one-way anova showed that there was statistically significant difference in the mean TDS values among the water sources in the dry season($p \leq 0.05$) while there was statistically insignificant difference in the mean TDS measurements among the water sources in the wet season (Table 2). From a total of 16 water samples tested for TDS from four water sources in the dry and the wet seasons, 16 (100%) had less than 1000 mgL^{-1} in each of the seasons Tables 3 and 4.

The results of nitrate fluctuated from 1.37 to 3.06 mgL^{-1} in the dry season. The uppermost value was occurred at ws_4 (3.06 mgL^{-1}).This was followed by ws_1 (2.10 mgL^{-1}), ws_2 (1.64 mgL^{-1}) and the lower values was detected from ws_3 (1.37 mgL^{-1}). In the wet season, the values of nitrate varied from 2.05 mgL^{-1} to 3.15 mgL^{-1}. Highest values were noticed from ws_4 (3.15 mgL^{-1}).The rest were found in order, ws_1 (2.82 mgL^{-1}), ws_2 (2.09 mgL^{-1}) and lowermost value of 2.05 mgL^{-1} from ws_3. Nitrate values in this study were found higher in the wet season than in the dry season across all the water sources. This might be due to the entrance of run off to the water sources that came from various anthropogenic activities. The results of nitrate among the water sources in the dry season revealed a significant variation since the p-value (0.00) is less than the significance level (0.05) (Table 1).In the same way, the results of nitrate in the means of the water sources was significant in the wet season because the p-value (0.04) is less than the significance level (0.05) (Table 2). All the water samples tested for nitrate from four water sources in both season, they were in the acceptable limit value (50 mgL^{-1}) of WHO standard Tables 3 and 4.

Results of ammonia varied between 0.20 mgL^{-1} to 0.24 mgL^{-1} in the dry season. Ws_3 had the higher value of 0.24 mgL^{-1}. This was followed by ws_1 (0.22 mgL^{-1}), ws_4 (0.21 mgL^{-1}) and the lowest value of ws_2 (0.20 mgL^{-1}). The result ranged from 0.07 mgL^{-1} to 0.36 mgL^{-1} in the wet season. Ws_1 had the uppermost value of 0.36 mgL^{-1}. This was followed by ws_2 (0.26 mgL^{-1}), ws_3 (0.16 mgL^{-1}) and ws_4 had the lower most value of 0.07 mgL^{-1}. Ws_1 and ws_2 had higher values in the wet season and lower values in the dry season whereas ws_3 and ws_4 had lower values in wet season and higher values in the dry season. The different value between the wet and dry season for ammonia is because of geological and physical factors. The result of one way anova indicated a statistically insignificant variation in water quality among the water sources in the dry season ($p \geq 0.05$).Nevertheless, there was a significant difference in water quality in terms of ammonia among the water sources in the wet season (Table 2). Comparing the total of thirty two water samples collected in the dry and wet season for ammonia with the water quality standards revealed that, all the water sources were found within the allowable limit of water quality standards of (1.50 mgL^{-1}) both in the dry and wet seasons(Tables 3 and 4).

The results of calcium was found in the range of 7.50 mgL^{-1} to 28.50 mgL^{-1} in the dry season. Ws_4 had the higher value of 28.50 mgL^{-1}. This was followed by ws_3 (17.00 mgL^{-1}), ws_2 (10.75 mgL^{-1}) and ws_1 (7.50 mgL^{-1}). The result ranged from 11.75 mgL^{-1} to 23.75 mgL^{-1} in the wet season. Ws_4 had the highest value of 23.75 mgL^{-1}, ws_3 (20.00 mgL^{-1}), ws_2 (17.50 mgL^{-1}) and ws_1 had the lowest value of 11.50 mgL^{-1}. Concentration of calcium was found to be higher in the wet season than in the dry season across all the sampling points with the exception of ws_4. The greater value of calcium in the wet season might be due to the dissolution from the rocks because of the natural occurrence of calcium in the earth crust. The result of one-way anova showed that there was statistically significant difference in the mean calcium measurements among the water sources in the dry season (Table 1) but the result of one way nova showed that there was no statistically significant difference among the mean values of calcium of the water sources in the wet season (Table 2). In a total of 32 water samples tested for calcium in both the dry and wet seasons, all calcium concentrations of water sources were acceptable by WHO standard.

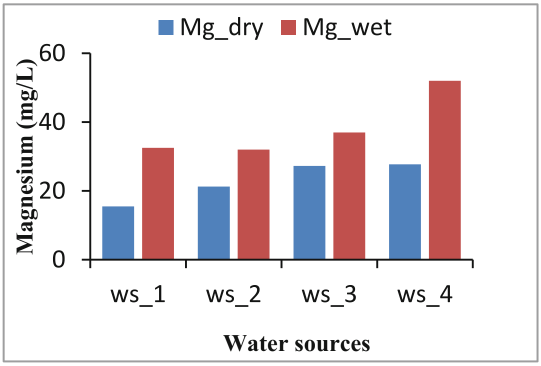

Fig. 4. Magnesium variation in season

The mean values of magnesium ranged from 15.50 to 27.75 mgL^{-1} in the dry season. The variation was found in this order ws_1 < ws_2 < ws_3 < ws_4. Ws_1 had the lowest value of 15.50 mgL^{-1} and ws_4 had the highest value of 27.75 mgL^{-1}. During wet season, the concentration of magnesium ranged from 32.00 to 52.00 mgL^{-1} in the order ws_2 < ws_1 < ws_3 < ws_4. Ws_4 had the highest value of 52.00 mgL^{-1} and ws_2 had the lowest value of 32.00 mgL^{-1}. The mean values of magnesium were higher in the wet season than in the dry season (Fig. 4). The reasons for such greater value of magnesium in the wet season across all the water sources might be due to washing of magnesium from the rocks containing a large number of minerals which held magnesium. According to the results of one way anova, there was a significant difference amongst the means of the water sources in both the two seasons (Tables 1 and 2). In analysis of the chemical quality of water samples for magnesium in the wet season, 2 (12.5%) water samples were greater than the recommended limit of WHO standard. Only 14 (87.5%) of water samples were found to be met the WHO standard acceptable limit (Table 3). From a total of 16 water samples collected from the water sources in the dry season for magnesium, all magnesium concentrations of water sources were acceptable by WHO standard (Table 4).

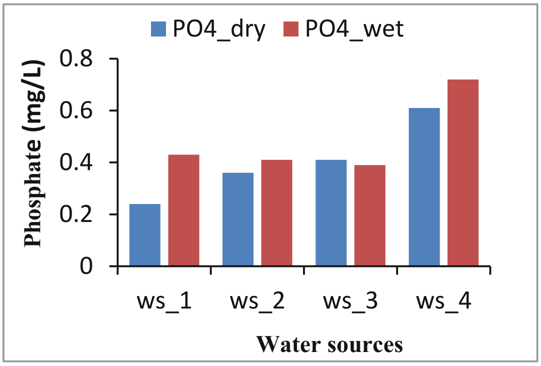

Fig. 5. Phosphate variation in season

The results of phosphate ranged from 0.24 to 0.61 mgL^{-1} in the dry season. Ws_4 had the highest value of 0.61 mgL^{-1}. Next to it was ws_3 (0.41 mgL^{-1}), ws_2 (0.36 mgL^{-1}) and ws_1 with the lowest value of 0.24 mgL^{-1}. In the wet season, the values of phosphate ranged from 0.39 to 0.72 mgL^{-1}. Ws_4 had the highest value of 0.72 mgL^{-1}, followed by ws_1 (0.43 mgL^{-1}), ws_2 (0.41 mgL^{-1}) and ws_3 with the lowest value of 0.39 mgL^{-1}. Values of phosphate from ws_1, 2 and 4 were higher in the wet season than the dry season whereas ws_3 was lower in the wet season than the dry season (Fig. 5). The mean values of phosphate among the water sources showed a significant difference in the dry season but did not revealed a significant variation in the wet season (Tables 1 and 2). Among 16 drinking water samples collected in the dry season from four water sources tested for phosphate, 13 (81.25%) were below the upper limit of WHO guideline value for phosphate <0.5 mgL^{-1} but 3 (18.75%) were above WHO guideline value for phosphate >0.5 mgL^{-1} (Table 3). The low level of compliance was occurred as ws_2 and the lower level of compliance was noticed from ws_4. In the wet season, water samples tested for phosphate from the water sources, 6 (37.5%) were above the limit value of WHO standard whereas only 10 (75.5%) of the water samples were in accordance with the limit value of WHO standard (Table 4). The low level of compliance was detected from ws_2.The lower level of compliance was occurred at ws_1 and the lowest level of compliance was shown from ws_4. The lower compliance of phosphate as ws_4 might be due to the entrance of agricultural run off as well as owing to run off from open grass land above the spring.

Iron values varied between 0.03 to 0.12 mgL^{-1} in the dry season. A higher iron value of 0.12 mgL^{-1} was detected from ws_1. This was followed by ws_3 (0.11 mgL^{-1}), ws_4 (0.04 mgL^{-1}) and ws_2 with the lowest value of 0.03 mgL^{-1}. In the wet season, the values of iron ranged between 0.11 mgL^{-1} to 0.17 mgL^{-1}. The values were obtained in this order ws_4 (0.17 mgL^{-1}), ws_1 (0.16 mgL^{-1}), ws_3 (0.12 mgL^{-1}) and ws_2 with the lowest value of 0.11 mgL^{-1}. Iron values in this research were found higher in the wet season than in the dry season across all the sampling points. The result of one-way anova showed that there was statistically significant difference in the mean iron values ($p \leq 0.05$) among the water sources in the dry season. However, there was no a statistically significant difference in the mean iron amounts ($p \geq 0.05$)

among the water sources in the wet season. In a total of 32 water samples tested for iron in both the dry and wet seasons, all iron concentrations of water sources were acceptable by WHO standard value of 0.3 $\mathrm{mgL^{-1}}$ (Tables 3 and 4).

3.2 Bacteriological Quality of Drinking Water Sources

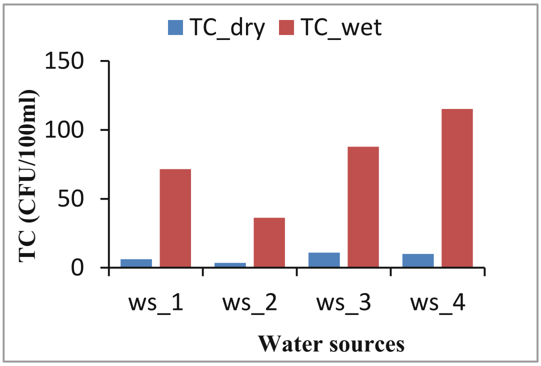

Fig. 6. Total coliform variation in season

Total coliforms ranged from 3.50 to 11.00 CFU in the dry season. Ws_3 recorded higher number of coliforms 11.00 CFU, ws_4 (10.00 CFU), ws_1 (6.25 CFU) and ws_2 recorded 3.50 CFU. In the wet season, the number of coliforms observed varied from 36.25 to 115.25 CFU with ws_4 having the highest number of coliforms 115.25 CFU, ws_3 (87.75 CFU), ws_1 (71.50) and ws_2 with the lowest number of coliforms 36.25 CFU. The total coliform counts were higher in the wet season than in the dry seasons across all the water sources (Fig. 6). The reasons for such greater values of total coliform in the wet season might be caused by the movement of organic matter from various human activities through run off. According to one way anova test, there was significant variation among the means of the water sources in the dry season (Table 1). Similarly, there was a significant difference among the water sources in the wet season since p-value (0.01) is less than the significance level (Table 2). From a total of 16 water samples tested for total coliform count from four water sources in the dry season, 16 (100%) were above the limit value of WHO standard (Table 3). Low compliance was observed from water samples collected from all the water sources in the dry season. Among 16 water samples collected and tested for total coliform in the wet season, 16 (100%) were above the upper limit of WHO guideline value but zero percent was in line with WHO guideline value across all the water sources (Table 4). The higher value of total coliform from ws_1 and ws_2 might be due to human, animal contact and storm run-off that came from poor sanitation system of both legally and illegally expanded urbanization around the sources. The highest total coliform from ws_4 might be due to human and animal contact.

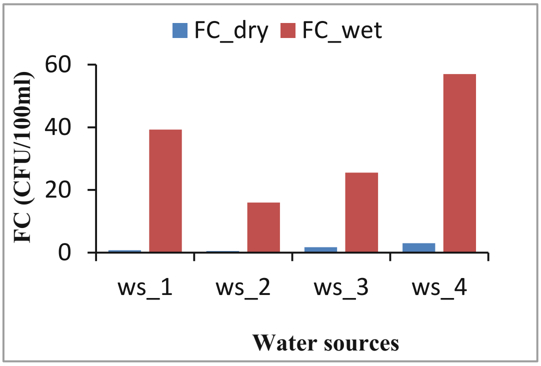

Fig. 7. Feacal coliform variation in season

Faecal coliform count values were found in the range of 0.50 to 3.00 CFU in the dry season with ws_4 having the highest value of 3.00 CFU and ws_3 (1.75 CFU), ws_1 (0.75 CFU) and ws_2 having the lowest value of 0.50 CFU. In the wet season, the value of faecal coliform ranged from (16.00 CFU to 57.00 CFU).The highest value of faecal coliform was observed from ws_4 (57.00 CFU).This was followed by ws_1 (39.25 CFU). Next to it was ws_3 (25.50 CFU) and the lowest value of 16.00 CFU was observed from ws_2. Values of faecal coliforms were found higher in the wet season than in the dry season across all the water sources (Fig. 7). The reasons for such greater value of faecal coliform in the wet season might be due to the transport and entrance of various human and animal feces to the water sources through run off which came from polluted surfaces. The result of one way nova showed that there was a statistically significant difference among the mean counts of faecal coliform (p 0.05) of the water sources in both the dry season ($p = 0.01$) and in the wet season ($p = 0.05$) (Tables 1 and 2).12 (75%) water samples in the dry season were unacceptable by WHO standard while 4 (25%) of the water samples were acceptable by WHO standard (Table 3). Low compliance was observed from water samples collected as ws_1 and ws_2 water sources. The lowest level of compliance was observed from water samples collected from ws_3 and ws_4. Among 16 water samples collected from four water sources tested for feacal coliform in the wet season, 16 (100%) water samples were above the upper limit of WHO guideline value but zero percent was in line with WHO guideline value (Table 4). The higher faecal coliform at ws_1 and ws_2 might be due to human and animal contact. The numerous feacal coliform from ws_4 might be due to feces of animals and humans that released from the above open grass land and open defecation of the rural residents above the grass land.

4 Conclusion

This study analyzed the drinking water sources quality variation and compliance in the dry and wet season based on thirteen water quality characteristics (total coliform, nitrate, electrical conductivity, turbidity, total dissolved solid, faecal coliform, calcium, magnesium, phosphate, iron, PH, temperature and ammonia) in Finote Selam town. Most parameters recorded greater values in the wet season and others were at their higher values in the dry season. The average values of turbidity (9.30 NTU), electrical conductivity (538.88 μscm^{-1}), total dissolved solid (296.38 mgL^{-1}), nitrate (2.39 mgL^{-1}), total coliform (77.69 cfu/100 ml), faecal coliform (34.44 cfu/100 ml), calcium (18.25 mgL^{-1}), magnesium (38.38 mgL^{-1}), phosphate (0.49 mgL^{-1}), iron (0.14 mgL^{-1}) and PH (5.90) were found higher in the wet season than in the dry season. Those of temperature (24.23 °C) and ammonia (0.22 mgL^{-1}) were found higher in the dry season than in the wet season. According to the analysis of the result, it may conclude that, the quality of water varies with the season. Turbidity, electrical conductivity, temperature, total dissolved solid, nitrate, total coliform, calcium, phosphate and iron showed a significant difference in the dry season while insignificant variation in the wet season. However, Faecal coliform and magnesium showed a significant variation both in the dry and wet season but ammonia revealed significant variation in the wet season and insignificant difference in the dry season. PH signified insignificant variation in both the dry and wet season. Based on anova, there is water quality variation among the water sources both in the dry and wet season. For turbidity 2 (12.5%),for phosphate 3 (18.75%), for electrical conductivity 16 (100%), for total coliform 16 (100%) and faecal coliform 12 (75%) were above WHO standard in the dry season whereas for turbidity 11 (68.75%), for electrical conductivity 14 (87.5%),for phosphate 6 (37.5), for total coliform 16 (100%), for magnesium 2(12.5%) and faecal coliform 16 (100%) were above WHO standard in the wet season. For PH 11 (68.75%) and 12 (75%) of the water samples collected were below the lower bound of WHO standard both in the dry and wet season respectively. The result showed that the drinking water sources are not safe since most of the water samples taken were not fulfilled WHO standard in the dry and wet season.

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