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Drinking Water Quality Test of Shambu Town (Ethiopia) from Source to Household Taps Using Some Physico-chemical and Biological Parameters

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ABSTRACT

Drinking water quality deterioration is a big issue in many countries which could be a result of many interconnected biological, physical, and chemical factors. Hence, cross-sectional study was carried out between January to August 2016 to evaluate the quality of Shambu town drinking water using some bacteriological and physicochemical parameters from sources to household tap distribution systems. A total of 117 samples were collected from two water sources (Fincha-Dabsa, and Gora), await well, a reservoir, and 9 household tap for three consecutive seasons. Biological and physicochemical parameters of the water showed highly significant variation ($P \leq 0.01$) based on sampling point except for pH, temperature (T) and electric conductivity (EC). Similarly, sampling time (seasons) has also a highly significant effect ($P \leq 0.01$) on pH, TºC, EC, and TDS; significant effect ($P \leq 0.05$) on Mn^{2+}, F^- and Cl^-. Total coliforms were negatively correlated to the tested chemical parameters except for Fe^{+2} and total hardness at α=0.05. The number of total coliforms in the water sample ranges from 4-35 CFU/100 ml but no fecal coliforms. pH, T and EC of the water ranges from 7.96-9.63, 7.6-17.6°C, and 80-248 μS/cm, respectively which was to the standard of WHO. Similarly, the maximum concentration (mg/l) of Fe^{+2}, Mn^{+2}, NO^{-3}, SO_4^{-2}, and PO_4^{-3} was 0.31, 1.24, 38, 3.6, and 0.86, respectively which qualifies the standard set by WHO and national drinking water minimum requirement. However, total dissolved solid and turbidity ranged in 62.73-154 mg/l and 4.23 NTU, respectively which requires further treatment to fit to the minimize national standard. Depending on the tested parameters (at the time), Shambu town drinking water has negligible health risk although continual testing is mandatory including other parameters.

INTRODUCTION

Water is perceived as ordinary, nevertheless the most remarkable substance. Life could not have evolved without water and dies without it. The body needs pure water for drinking and parameters of quality-drinking water varies based on organizations and countries. Most developed countries have zero tolerance for microbiological parameters like coliform and radioactive chemicals. Besides, other chemical elements and compounds such as fluoride, nitrate/nitrite, phosphate, Chloride, Iron, Manganese, Sulphate, and Sodium have a maximum tolerance level. Drinking water also characterized by an optimum level of pH, turbidity, taste, odour, conductivity, and color. Nowadays, the most significant pollutants of drinking water are pesticides and herbicides from agricultural fields by leeching [1].

In general, water pollution can occur from an identifiable source and unidentifiable source. Point sources of pollutant are those which have a direct injection into the water body from factories, wastewater effluent, and oil spill of tankers. Whereas, non-point sources of pollutant are those which arrive from different sources of origin and number of ways from different nonidentifiable sources. Sometimes pollution that enters the environment in one place has an effect at hundreds or thousands of miles, and pollution depends on seasonal variation [2].

Ethiopia has planned to attain 98.5% of drinking water supply to the community in the Second Growth and Transformation National plan (2015/16–2019/20). However, quality did not give similar attention. As a result, assessment of bacteriological and physicochemical qualities of urban source water and tap water distribution systems in major Cities of Ethiopia such as Addis

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Ababa [3], Dire Dawa [4] and Adama [5,6] showed the un potability of the water according to the world standard [7]. Similarly, drinking water assessment survey conducted in towns of Western Ethiopia like Gimbi town [8] and Nekemte town [9], and showed similar contaminations and pollution properties.

Poor quality of drinking water could be associated with either source of water or inefficiency of the treatment method. Most drinking water in Ethiopia is from surface water and groundwater. Both are heavily influenced by the method of soil management in the area although it passes through slow-sand filtration and chlorination treatment method. These treatment methods hardly give warranty to the quality of drinking water. Shambu town obtains drinking water from two ground sources. However, the quality of the water is yet not tested. The objective of this study was to assess the quality of shambu town drinking water.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in Shambu town (altitude of elevation of 2503 m a.s.l; $9^0$33' 00"N- $9^0$35' 25"N; $37^0$05' 05"E-$37^0$07'55"E), Ethiopia has a population size of 67, 279 [10]. There are about 11, 174 households possessing tap water pipelines at home level. The town gets its tap water from two sources called Fincha- dabsa (FD) and Gora (GW) ground waters. These sources are about one kilometer far from the town and sounded by agricultural lands and cattle grazing fields. The climatic condition of the area is characterized by four seasons namely the dry-Winter (December-February), the rare rainy-Autumn (March-May), the rainy-summer (June-August) and the sunny-Spring (September-November). The coldest months of the area are October, November, and December where the mean monthly temperature ranges from 8.9°C to 10°C. On the other hand, January and February months are the warmest months of the area with a mean monthly temperature, rising to 18°C and 26°C during the night and daytime respectively.

Sampling Techniques

Water samples were taken in triplicates during the month of January-August 2016 within an interval of two weeks from 13 sampling sites (Fincaha-Dabsa and Gora groundwater sources, wait well, reservoir and nine household taps water). The collection was done using sterile glass bottles (0.5 l) labeled with identification numbers. Purposive sampling was employed for sampling site selection and cluster sampling for household selection.

Determination of Bacteriological Parameters

Water samples were transported in a cold box containing ice freezer packs. Total coliform and Fecal coliform counts were carried out by membrane filtration technique according to APHA [11] in Microbiology Laboratory of Wollega University and Oromia Western Zonal Health laboratory (Nekemte town). The cultures were incubated at 37˚C and 44.5˚C for 24 hours for total coliforms determination and thermotolerant coliforms, respectively. All yellow colonies were counted and recorded as total coliforms and those that grew at 44.5˚C as fecal coliforms [12].

Determination of Physicochemical Parameters

Analysis of the physicochemical parameters of the water samples **(Table 1)** such as pH, Temperature (T), electrical conductivity (EC), total dissolved solids (TDS), Total suspended solids (TSS), Turbidity (TURB) ,and the chemical water quality parameters (Fe^{+2}, Mn^{+2}, NO_{3-}, SO_4^{-2}, PO_4^{-3}, F^-, Cl^-, total hardness, TH) were conducted in laboratory of Fincha'a Sugar Factory (Horo Guduru Wollega, Ethiopia). Sample preparation and analysis were done based on the standard test guidelines of APHA [12].

Table 1. Methods employed to measure physicochemical and Biological parameters of the water sample.

No	Parameter	Method
1	pH	pH meter
2	Temperature (˚C)	Thermometer
3	Electrical conductivity (mS/cm)	Conductivity meter
4	Total dissolved solids (mg/l)	Conductometry
5	Total suspended solids (mg/l)	filtration processes
6	Turbidity (NTU)	Turbidometer
7	Iron (mg/l)	Spectrophotometer
8	Manganese (mg/l)	Photometry
9	Nitrate (mg/l)	Colorimetric
10	Sulphate (mg/l)	Turbidimetric
11	Phosphate (mg/l)	Calorimeter
12	Fluoride (mg/l)	Spectrophotometer
13	Chlorine (mg/l)	Titration
14	Total hardness (ppm)	EDTA titration
15	Total coliforms (CFU/100ml)	Membrane Filtration
16	Fecal coliforms (CFU/100ml)	Membrane Filtration

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Data Analysis

The biological and physicochemical parameters data were organized and one-way ANOVA (Turkey's tests) was used to test the significant difference between the mean of the parameters using SPSS version-20 at α=0.05. A general linear model was conducted to test the effect of sampling site and sampling season on water quality parameters. The correlation between bacteriological and physicochemical parameters was analyzed by Pearson correlation coefficient at P<0.05 and the significance level was also used to indicate the associations between parameters.

RESULTS AND DISCUSSION

Bacteriological Water Quality Tests

The water sample collected from sources (FD, GW), WW, RES, and at household (HH1-HH9) has no fecal coliform bacteria which is in accordance with the standard of WHO [13]. However, the total coliform in the water sample from all sampling site was higher than the lower limit of WHO [13] standard **(Table 2)**. The number of total coliform in the sample sites range from 4 CFU/100 ml (HH2, HH5, HH8) to 151 CFU/100 ml (HH1) which are significantly different from each other. The maximum number of total coliform was 151 CFU/100 ml from HH1 followed by 20 ± 1 CFU/100 ml from HH9. However, other household water samples showed significantly lower (α=0.05) number of total coliform as compared to HH1 and HH9 **(Table 2)**. The water samples collected from household showed the significantly lower number of total coliform after treatment in the reservoir except for HH1 which showed the relatively efficient chlorination. The unusual significantly higher number of total coliform in a sample of HH1 could be associated with the leak of the specific pipeline. The other factor that contributes to the HH1 total coliform could be associated with the irregular availability of water across the line which gives chance to the stability of microorganisms for reproduction in a specific area. Relatively, a bacteriological parameter of Shambu town drinking water is good as compared to drinking water from Jimma zone that showed a fecal coliform in the range of 1-266 CFU/100 ml [14].

Table 2. Mean count of total coliform and fecal coliform in Shambu town drinking water from the months January to August 2016. Keys: TC: total coliform, FC: Fecal coliform, FD: Fincha dabsa dug well water source, GW: Gora Wellspring water source, WW: Wait Well from FD and GW sources, RES: Reservoir, HH1-HH9: household tap water sampling points labeled as one to nine households; AC: acceptable, UA: Unacceptable compared to WHO, U.S. Environmental Protection Agency (EPA), American Public Health Association (APHA), and Quality and Standards Authority of Ethiopia (QSAE). Numbers indicated by the same letters across column are not significantly different from each other at α=0.05.

Sampling point	Biological Parameters			
	TC (CFU/100 ml)	Status according to WHO, EPA, APHA, and QSAE	FC (CFU/100 ml)	AC/UA
FD	31.58	unacceptable	0	acceptable
GW	33.58	unacceptable	0	acceptable
WW	2	unacceptable	0	acceptable
RES	61.00	unacceptable	0	acceptable
HH1	151.0	unacceptable	0	acceptable
HH2	4	unacceptable	0	acceptable
HH3	8	unacceptable	0	acceptable
HH4	12 ± 1.0	unacceptable	0	acceptable
HH5	12 ± 1.0	unacceptable	0	acceptable
HH5	4 ± 1.0	unacceptable	0	acceptable
HH6	6 ± 1.0	unacceptable	0	acceptable
HH7	6 ± 1.0	unacceptable	0	acceptable
HH8	4 ± 1.0	unacceptable	0	acceptable
HH9	20 ± 1.0	unacceptable	0	acceptable

The irregular chlorination of Shambu town drinking water takes place in the reservoir. However, the number of total coliform in the reservoir (61.0 CFU/100 ml) is exceptionally higher as compared to the sources **(Table 2)**. Besides, this could be also related to the very low dose of chlorine added during the treatment. This was evidenced by total chlorine residue, in which the concentration was insignificantly different at source wait well and reservoir. Chlorine is an effective disinfectant and easy to handle. The capital costs of chlorine installation are low, simple to for application and control. However, chlorination efficiency depends on chlorine residual, contact time, the type of chemical used and location in the treatment process. The chlorine demand involves the reaction of chlorine with compounds in water, reducing the amount of chlorine available to kill microorganisms [15].

According to WHO [13], Shambu town drinking water is categorized into two risk levels based on total coliform. 54 of the sampling points (66.67%) were in low-risk level (1-10 CFU/100 ml) and 27 of the samples (33.37%) were in the medium risk level (11-100 CFU/100 ml). The absence of FC in the study area might be associated with the specific climatic condition of the study like low temperature during the study time (10°C). Previous research also showed the impact of low temperature (15-25°C) on the growth and survival of total coliform, *E. coli* and Heterotrophic bacteria in drinking water [16]. Besides, the source of the drinking water is out of the town (1 km) that hardly have contact with municipal wastes special with mesophilic fecal coliforms. Therefore, the absence of fecal coliform in drinking water might indicate the absence of contact of the water source and lines with recent fecal sources.

Physical Water Quality Tests

pH of the water samples was in the range of 7.96-9.63 **(Table 3)** indicating the slightly alkaline nature of the water because normal pH range of drinking water is 6-8.5 [13]. pH is mostly a result of natural geological conditions at the site and the type of minerals found in the local rock. Water with pH a value greater than 7 indicates alkalinity and tends to affect the taste of the water. Alkaline drinking water may take on a “soda” taste. Therefore, pH adjustment should be conducted at the treatment point [17]. The temperature range of Shambu drinking water ranges in 7.6-17.6°C **(Table 3)**. It is recommended to keep drinking water at 20°C [18]. This temperature hinders mesophilic pathogenic bacteria. Therefore, Shambu drinking water is in the recommended range of temperature that contributed to the poor growth of coliform bacteria **(Table 2)**.

Electric conductivity (EC) of shambu town drinking water ranged from 80-248.96 µS/cm **(Table 3)**. The highest EC was water sample collected from for HH2 and the lowest was HH9 which was significantly different from each other at $\alpha=0.05$. The optimum range for drinking water 0-800 µS/cm [19]. Therefore, based on EC Shambu town drinking water was in the acceptance range. However, the significant variation between the two sampling could be related to the turbidity of the water as shown in **Table 3** because EC gives an indication of the amount of TDS in water [20].

The other parameter used to test the quality of drinking water is Total Dissolved Solids (TDS). It is the term used to describe the inorganic salts and small amounts of organic matter present in water solution [21]. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions. TDS of Shambu drinking water was in the range of 62.73 to 154 mg/l by HH1 and WW, respectively. According to WHO [21], optimum range for hardness (calcium and magnesium) in drinking water is 100-500 mg/l. Therefore, Shambu drinking water at household levels was considered as “poor” in mineral content [22] because the minerals are needed in the diet. In addition, mineral shall do the balance of body ions and energy. Besides, the taste of water containing low mineral is sour or flat. On the other hand, water containing excess minerals tastes metallic, salty, earthy etc. [23]. Therefore, a significant deviation of TDS level in drinking water from the standard values is unacceptable to consumers not only because of taste but also due to the dietary factor.

Table 3. Mean of Physical properties of Shambu town drinking water between January and August 2016. Keys: Numbers indicated by the same letters across Colum are not significantly different from each other at $\alpha=0.05$. FD: Fincha dabsa dug well water source, GW: Gora spring water source, WW: Wait well (water from FD and GW sources), SP: sampling point, HH1 to HH9: Households labeled as sampling points one up to nine, T: Temperature, EC: Electrical conductivity, TDS: Total dissolved solids, TSS: Total suspended solids, TURB: Turbidity.

Physical Parameters						
SP	**pH**	**T(°C)**	**EC (µS/cm)**	**TDS (mg/l)**	**TSS (mg/l)**	**TURB (NTU)**
FD	9.63	10 ± 0.1k	212 ± 0.4	120 ± 0.1	0.06	3.4
GW	6.16 ± 0.1	7.66 ± 0.1	119.2 ± 0.1	29.83 ± 0.1	0.286	4.23
WW	8.03	11.0 ± 0.1	143.3 ± 0.1	154.0 ± 0.	0.183	2.89
RES	8.13 ± 0.1	17.6 ± 0.	135.4	93.2 ± 0.2	0.027	1.4
HH1	8.12 ± 0.1	14.76 ± 0.1	134.16 ± 0.1	62.73 ± 0.1	1.027	2.5
HH2	7.96 ± 0.1	15.03 ± 0.1	248.96 ± 0.1	90.26 ± 0.1	0.032	1.31
HH3	8.2 ± 0.1	16.26 ± 0.1	151.17	93.9 ± 0.1	0.04	1.59
HH4	8.03 ± 0.1	13.5 ± 0.1	146.5	91.2 ± 0.1	0.037	1.83
HH5	8.23 ± 0.1	12.9 ± 0.1	152.03 ± 0.1	95.83 ± 0.1	0.033	1.42
HH6	8.23 ± 0.1	14.7 ± 0.1	146.9 ± 0.1	91.16 ± 0.1	0.143	1.4
HH7	8.36 ± 0.1	14.83 ± 0.1	148.43 ± 0.1	95.5 ± 0.1	0.034	1.6
HH8	8.36 ± 0.1	13.93 ± 0.1	150.43 ± 0.1	91.03 ± 0.1	0.014	1.26
HH9	8.63 ± 0.1	9.53 ± 0.1	80 ± 0.1	90.63 ± 0.1	0.24	2.57

Total Suspended Solids (TSS), also known as non-filterable residue, are those solids (minerals and organic material) that remain trapped on a 1.2 µm filter [24]. Suspended solids can enter groundwater through runoff from industrial, urban or agricultural areas and reduce water clarity [25]. In this test, Shambu town drinking water showed the maximum TSS of 1.027 mg/l at household level of HH1 **(Table 2)**. This value is very low as compared to TSS of Spring Water in Arbaminch and drinking water of different sources in Jimma zone that showed a maximum of TSS of 62 mg/l and 403.33 mg/l, respectively. The other physical parameter used to test water quality is turbidity. Turbidity describes the cloudiness of water caused by suspended particles such as clay and silts, chemical precipitates and organic particles [26]. Turbidity reduces the clarity of the water. Sources of Shambu drinking water showed the highest turbidity with a maximum of 4.23 NTU at GW. The household HH1 and HH9 also showed 2.89 NTU and 2.57 NTU, respectively. According to WHO [7], the turbidity of drinking water at household level should be kept below 0.2 NTU although at this point still, it requires disinfection to protect *Cryptosporidium* breakthrough. Therefore, based on turbidity Shambu drinking water requires intensive treatment.

Chemical Water Quality Tests

The Fe^{+2} and Mn^{2+} of Shambu drinking water were in the range of 0.016-0.31 mg/l and blow detectable level to 1.24 mg/l, respectively. Currently, recommended limit for Fe^{+2} and Mn^{2+} in drinking water is 0.3 mg/l and 0.05 mg/l, respectively [27]. When the level of Fe^{+2} exceeds the limit, water experience red, brown, or yellow in different water utilities. Similarly, high levels of Mn^{2+}

also cause objectionable tastes in the water but there are no particular toxicological connotations [7]. Besides, the organic compound nitrate, sulfate, and phosphates in Shambu drinking water were in the range of 0.3-38 mg/l, below the detectable level to 3.6 mg/l and 0.24-0.86 mg/l, respectively **(Table 4)** which is below the maximum limit set by WHO [7]. High levels of nitrate and sulfate in drinking water may induce "blue baby" syndrome (methemoglobinemia) and laxative effect, respectively.

Table 4. Mean of Chemical properties of Shambu town drinking water between January and August 2016. Keys: Values designated by the different latter across column indicated the absence of significant variation at α=0.05. FD: Fincha-dabsa dug well water source, GW: Gora spring water source, WW: Wait well (water from FD and GW sources), SP: sampling point, HH1 to HH9: Households labeled as sampling points one up to nine.

	Chemical Parameters							
SP	**Fe^{2+} (mg/l)**	**Mn^{2+} (mg/l)**	**NO_3^- (mg/l)**	**SO_4^{2-} (mg/l)**	**PO_4^{3-} (mg/l)**	**F^- (mg/l)**	**Cl (mg/l)**	**TH (mg/l)**
FD	0.18[a]	0.26	4.86 ± 0.1	1.6 ± 0.1	0.24	0.21	0.007	19.0 ± 0.1
GW	0.31[ab]	0.80	0.3 ± 0.1	BDL	0.30	0.74	0.006	47.3 ± 0.1
WW	0.05[b]	BDL	8.16 ± 0.1	1.6 ± 0.1	0.38	0.92	0.004	50.6 ± 0.1
RES	0.176[a]	0.60	1.4 ± 0.1	0.8 ± 0.1	0.64	0.64	0.023	48.6 ± 0.1
HH1	0.11[a]	0.23	1.0 ± 0.1	1.4 ± 0.1	0.77	1.19	0.012	34.3 ± 0.1
HH2	0.016[b]	0.27	17.1 ± 0.1	1.8 ± 0.1	0.47	0.96	0.035	37.6 ± 0.1
HH3	0.04[b]	1.24	1.06 ± 0.1	3.6 ± 0.1	0.86	1.0	0.019	37.6 ± 0.1
HH4	0.09[b]	0.40	20.5 ± 0.1	2.6 ± 0.1	0.59	0.57	0.11	34 ± 0.1
HH5	0.04[b]	0.25	38 ± 0.1	2.6 ± 0.1	0.85	0.77	0.067	33.3 ± 0.1
HH6	0.11[ab]	0.95	28.0 ± 0.1	3.6 ± 0.1	0.63	0.99[d]	0.065	36.3 ± 0.1
HH7	0.09[b]	1.02	25.83 ± 0.1	0.8 ± 0.1	0.66	1.29	0.033	24.0 ± 0.1
HH8	0.06[b]	BDL	8.26 ± 0.1	0.8 ± 0.1	0.54	0.91	0.13	35.3 ± 0.1
HH9	0.11	0.34	3.0 ± 0.1	0.8 ± 0.1	0.44	1.10	0.016	40.6 ± 0.1

The World Health Organization [13] concluded that there is no nutritional basis for the regulation of phosphorus levels in the US drinking water supplies. However, to control eutrophication, USEPA makes the following recommendations:

1. Total PO4-P ≤ 0.05 mg/L in a stream at a point where it discharges into a lake or reservoirs
2. Total PO4-P ≤ 0.1 mg/L in streams that do not discharge directly into lakes or reservoirs
3. Total PO4-P ≤ 0.025 mg/l for reservoirs [28]

Therefore, phosphate content of Shambu drinking water was fairly higher than the recommended level of by WHO [13].

The level of fluorine and chlorine in Shambu drinking water samples ranges from 0.21-1.29 mg/l and ≤ 0.13 mg/l, respectively **(Table 4)**. According to WHO [7], the optimum level of the two minerals in drinking water is 0.6 mg/l and 250 mg/l, respectively. The excessive presence of fluorine in water results in the occurrence of dental fluorosis and the lower concentration result in tooth decay. The excessive concentration of chlorine in drinking water gives a salty test of the water that cannot cut thirsty but lower concentration affects the treatment process. In general, according to WHO [7], the chemical parameters tests for Shambu drinking fits the standard except for the excessive amount of Mn and an insufficient amount of Cl compounds.

Correlations between Bacteriological and Physical Parameters

Total coliform were negatively correlated to the chemical parameters of the water except for Fe^{+2} and TH. TC showed positive and strong correlation (α=0.01) with Fe^{+2}, and negative and strongly correlated to Cl^- at α=0.05 **(Table 5)**. Besides, TC was strongly positive and strongly negatively correlated with turbidity and temperature, respectively.

Table 5. Correlations between Bacteriological and Physiochemical parameters of Shambu drinking water.

		Biological and Physical parameters						
		TC	**pH**	**T**	**EC**	**TDS**	**TSS**	**Turb**
Chemical parameters	Fe	.70**	-0.42	-0.49	-0.3	-0.54	0.19	.72**
	Mn	-0.1	-0.23	0.28	-0.15	-0.33	-0.17	-0.1
	NO3	-0.517	0.11	0.18	0.219	0.17	-0.36	-0.51
	SO4	-0.43	0.27	0.41	0.24	0.28	-0.17	-0.46
	PO4	-0.55	0.06	0.54	-0.1	-0.08	0.18	-0.47
	F	-0.14	-0.17	0.1	-0.23	-0.12	0.29	-0.07
	Cl	-.56*	0.07	0.26	0.043	-0.02	-0.35	-.58*
	TH	0.03	-.63*	-0.05	-0.41	0.08	0.08	0.12
	TC	1	-0.15	-.84**	-0.17	-0.1	0.27	.98**

**: Correlation is significant at the 0.01 level (2-tailed), *: Correlation is significant at the 0.05 level (2-tailed).

pH also strongly negatively correlated with TH; and TDS were positively correlated with NO_{3-}, SO_{4-} and TH. Besides, TH was significantly positively correlated with PO_4-, F^- and TH **(Table 5)**. Similarly, previous research also showed a correlation between biological and physic-chemical properties of drinking water [29].

Effect of Sampling Points and Sampling Season on Bacteriological and Physicochemical Parameters

Shambu town drinking water samples were taken from the source up to the household level in three different seasons. Biological and physicochemical parameters of the water samples showed highly significant variation (P ≤ 0.01) based on sampling point except for pH, temperature, and EC **(Table 6)**. The effect of sampling point and its characteristics on microbiological parameters is indicated in WHO [30].

Table 6. Effect of sampling points and Sampling Seasons on Bacteriological and Physico-chemical parameters.

SV	Parameter (P-values)												
	TC	pH	T°	EC	TDS	TSS	TURB	Fe^{2+}	Mn^{2+}	NO_3^-	SO_4^{2-}	PO_4^{3-}	F^-	Cl^-
SP	**	NS	NS	NS	**	**	**	**	**	**	**	**	**	**
SS	NS	**	**	**	**	NS	NS	NS	*	NS	NS	NS	*	*

**: Highly significant (P ≤ 0.01), *: Significant (P ≤ 0.05), and NS=Non-significant (P>0.05). SV: Source of variation, SP: Sampling point, SS: Sampling season, T: temperature, EC: Electrical conductivity, TDS: Total dissolved solids, TSS: Total suspended solids, TURB: Turbidity.

Sampling time (seasons) has also a highly significant effect (P ≤ 0.01) on pH, T, EC, and TDS. Similarly, Mn^{2+}, F^- and Cl^- showed significant variation based on sampling time (P ≤ 0.05). Whereas, TC, TSS, TURB, Fe^{+2}, NO_{3-}, $SO_4^{-2,}$ and PO_4^{3-} did not show variation (P>0.05) based on sampling seasons **(Table 6)**. Previous research also showed the significant effect of seasonal variations on physic-chemical parameters of drinking water [31].

CONCLUSION

Quality of Shambu town drinking water was tested at three different seasons from source to household tap. Results of most of the parameters significantly varied based on sampling time and sampling point. Fecal coliforms were not detected in the water sample although the total coliforms showed a deviation from the standard set by international and national drinking water standard. Except for total dissolved solids and turbidity, the physicochemical parameters tested for Shambu town drinking water satisfies the national quality standard (at the time of the study) although continual testing is necessary including other quality parameters.

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