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Original Research

Physicochemical and Biological Parameters of Domestic Tap Water of Nedjo Town from Source to Households, Ethiopia

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Abstract

Poor quality of drinking water is one of the major causes of waterborne diseases in Ethiopia. A cross-sectional study was conducted to evaluate the physicochemical and bacteriological properties of Nejo town drinking water from sources, reservoirs, and distribution systems (household taps) from January to August 2020. A total of 117 samples were taken from eight sampling sites: three treatment points, one reservoir, and four Kebeles through the watercourse during the dry and rainy seasons. The water samples were determined for pH, temperature (TO), electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), turbidity, Fe^{+2}, Mn^{+2}, NO^{3-}, SO_4^{-2}, PO_4^{-3}, F^-, Cl^-, total hardness (TH), total coliforms (TC), and faecal coliforms (FC). The parameters showed significant variation based on sampling point and sampling time, except pH, TO EC, and TDS. There was a negative correlation between TC and chemical parameters except for Fe^{+2} and TH at $\alpha = 0.05$. The number of TC in the water samples ranges from 3–31 CFU/100 mL, but there are no faecal coliforms. The pH, TO, and EC of the water ranged from 6.66–8.13, 11.53–17.6 ºC, and 218–393 µS/cm, respectively, which was to the standard of the WHO. Similarly, the maximum concentration (mg/L) of Fe^{+2}, Mn^{+2}, NO_3^-, SO_4^{2-}, and PO_4^{3-} was 0.22, 1.24, 38, 3.6, and 0.86, respectively, which qualifies the standard set by WHO and the national drinking water minimum requirement except NO_3^-. However, total dissolved solids and turbidity ranged from 62.73–154 mg/L and 4.23 NTU, respectively, which require further treatment to fit into the minimum national standard. Depending on the tested parameters at the time, Nedjo town drinking water has negligible health risks, although continual testing is mandatory, including other parameters.

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INTRODUCTION

Water is perceived as ordinary, yet it is nevertheless the most remarkable substance. Humans wash in it, fish in it, swim in it, drink it, and cook with it, and about two-thirds of our body is water. Life could not have evolved and died without water. The body needs pure water for drinking, and the parameters of quality drinking water vary based on organisations 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 maximum tolerance levels. Drinking water is also characterised by an optimum level of pH, turbidity, taste, odour, conductivity, and colour (WHO, 2008). Today, the most significant pollutants in drinking water are pesticides and herbicides leeched from agricultural fields (Chaudhry & Malik, 2017).

In general, water pollution can occur from identifiable and unidentifiable sources. Point sources of pollutants are those that have a direct injection into water bodies from factories, wastewater effluent, and oil spills from tankers. Non-point sources of pollutants are those that arrive from different sources of origin and, in several ways, from different non-identifiable sources. Sometimes pollution that enters the environment in one place has an effect for hundreds or thousands of miles, and pollution depends on seasonal variation (Brainerd & Menon, 2014).

Ethiopia has planned to attain 98.5% of the drinking water supply to the community in the Second Growth and Transformation National Plan (2015/16–2019/20). However, the quality did not receive similar attention. As a result, evaluations of the bacteriological and physicochemical characteristics of urban source water and tap water distribution systems in significant Ethiopian cities like Addis Ababa (Abera et al., 2014), Dire Dawa (Amenu et al., 2013), and Adama (Eliku & Sulaiman, 2015) revealed that the water was unpotable by the WHO standard (WHO, 2011). Similarly, a drinking water assessment survey conducted in towns in Western Ethiopia like Shambu town (Garoma et al., 2018) and Nekemte town (Kedir et al., 2017) showed similar contamination and pollution properties.

Poor-quality drinking water could be associated with either the source of the water or the inefficiency of the treatment method. Most drinking water in Ethiopia comes from surface water and groundwater. Despite passing through slow-sand filtration and chlorination treatment procedures, both are significantly impacted by the local soil management strategy. These treatment methods hardly give a warranty on the quality of drinking water. Nedjo Town obtains drinking water from three ground sources. However, the quality of the water has not yet been tested. The objective of this study was to assess the quality of Nedjo town's drinking water using bacteriological and physicochemical parameters.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Nedjo town (altitude of elevation 1,821 m a.s.l.; 9°30′ N, 35°30′ E; 9.500° N, 35.500°E), 515km away from Addis Ababa in the western part of Ethiopia. Its mean annual temperature is about 18.6 °C, and its annual rainfall is about 1,350 mm (Ethiopian Metrological Agency, Nedjo Branch, 2018). Regarding its soil types, the majority of the area has red clay soil covered with moderately sedimentary rocks, and it also has rugged topography. The climatic condition of the area is characterised by four seasons: the dry winter (December–February), the rare rainy autumn (March–May), the rainy summer (June–August), and the sunny spring (September–November).

Sampling techniques

Water samples were taken in triplicate during January–August 2019 within two weeks from eight sampling sites (three treatment points, one reservoir, and four kebeles). The collection was done using sterile glass bottles (0.5 L) labelled 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 and freezer packs. According to Hach et al. (1997), total coliform and faecal coliform counts were performed by membrane filtration method in the Western Oromia Zonal Health Laboratory (Nekemte Town) and the Microbiology Laboratory of Wollega University. The cultures were incubated at 37°C and 44.5 °C for 24 hours for total coliform determination and thermo-tolerant coliforms, respectively. All yellow colonies were counted and recorded as total coliforms and those that grew at 44.5°C were faecal coliforms (Rice et al., 2012).

Determination of physicochemical parameters

Analysis of the physicochemical parameters of the water samples, 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-, and total hardness, TH), was conducted in the laboratory of the Nekemte Water and Sewage Laboratory, Nekemte, Ethiopia. Sample preparation and analysis were done based on the standard test guidelines of Rice et al. (2012).

Table1

Methods employed to measure physicochemical and Biological parameters of water samples

No	Parameter	Method
1	pH	pH meter
2	Temperature (ºC)	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

Data Analysis

The biological and physicochemical parameter data were organised, 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 $\alpha = 0.05$. A general linear model was conducted to test the effect of the sampling site and sampling season on water quality parameters. The correlation between bacteriological and physicochemical parameters was analysed by the Pearson correlation coefficient at $P<0.05$ and the significance level was also used to indicate the associations between parameters.

RESULTS AND DISCUSSION

Bacteriological parameters of the water

The water sample collected from sources, RES, and households (from four kebeles) has no faecal coliform bacteria, which is by the standard of WHO (2008). However, the total coliform in the water sample from all sampling sites was higher than the lower limit of the WHO (2008) standard (Table 2). The number of total coliforms in the sample sites ranges from 4 CFU/100 mL (HH2, HH5, and HH8) to 151 CFU/100 mL (HH1), which are significantly different from each other. The maximum number of total coliforms was 151 CFU/100 mL from HH1, followed by 20±1 CFU/100 mL from HH9. However, other household water samples showed a significantly lower (α = 0.05) number of total coliforms as compared to HH1 and HH9 (Table 2). The water samples collected from households showed a significantly lower number of total coliforms after treatment in the reservoir, except for HH1, which showed relatively efficient chlorination. The unusually significant higher number of total coliforms in a sample of HH1 could be associated with a leak in 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 a chance to the stability of microorganisms for reproduction in specific areas. Relatively, the bacteriological parameters of Nedjo town drinking water are good as compared to drinking water from the Jimma zone, which showed a faecal coliform in the range of 1-266 CFU/100 mL (Yasin *et al*., 2015).

Table 2

Mean count of total coliform and faecal coliform in Nedjo town drinking water from Jan. to Aug. 2019

Sampling point	Biological Parameters			
	(CFU/100mL)	Status according to WHO, EPA, APHA, and QSAE	(CFU/100mL)	AC/UA
SR	31.58^{d}	Unacceptable	0	Acceptable
RES	61.00^{c}	Unacceptable	0	Acceptable
HH1	151.0^{a}	Unacceptable	0	Acceptable
HH2	4^{k}	Unacceptable	0	Acceptable
HH3	8^{i}	Unacceptable	0	Acceptable
HH4	12±1.0^{h}	Unacceptable	0	Acceptable
HH5	12±1.0^{h}	Unacceptable	0	Acceptable
HH5	4±1.0^{k}	Unacceptable	0	Acceptable
HH6	6±1.0^{j}	Unacceptable	0	Acceptable
HH7	6±1.0^{j}	Unacceptable	0	Acceptable
HH8	3±1.0^{k}	Unacceptable	0	Acceptable
HH9	20±1.0^{f}	Unacceptable	0	Acceptable

Keys: TC, total coliform; FC, faecal coliform; SR, source; RES, reservoir; and HH1-HH9, household tap water sampling points labelled as one to nine households; AC, acceptable; UA, unacceptable, compared to WHO, the U.S. Environmental Protection Agency (EPA), the American Public Health Association (APHA), and the Quality and Standards Authority of Ethiopia (QSAE). The numbers indicated by the same letters across the column are not significantly different from each other at α = 0.05.

Irregular chlorination of Nedjo town drinking water takes place in the reservoir. However, the number of total coliforms in the reservoir (61.0 CFU/100 mL) is exceptionally high as compared to the sources (Table 2). Besides, this could also be related to the very low dose of chlorine added during the treatment. This was evidenced by total chlorine residue, whose concentration was insignificantly different at the source and reservoir (Table 4). Chlorine is an effective disinfectant that is easy to handle. The capital costs of chlorine installation are low and simple to apply and control. However, chlorination efficiency depends on chlorine residual, contact time, 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 (Mi et al., 2015).

According to WHO (2008), Nedjo town drinking water is categorised into two risk levels based on total coliform. 54 of the sampling points (66.67%) were at a low-risk level (1–10 CFU/100 mL), and 27 of the samples (33.37%) were at a medium-risk level (11–100 CFU/100 mL). The absence of FC in the study area might be associated with the specific site of the source and its treatment efficiency. The source of the drinking water is out of town (1km) and has hard contact with municipal waste, especially mesophilic faecal coliforms. Therefore, the absence of faecal coliform in drinking water might indicate the absence of contact with the water source and lines with recent faecal sources.

Physical parameters of the water

The pH of the water samples was in the range of 6.66–8.13 (Table 3), indicating the neutral nature of the water. According to WHO, the pH range of drinking water is 6–8.5 (WHO, 2008). The pH is mostly a result of the natural geological conditions at the site and the types of minerals found in the local rock. The big deviation in water pH from 7 brings poor palatability because of the test. During this condition, pH adjustment should be conducted at the treatment point (Wagenet *et al*., 1995). The temperature range of Nedjo drinking water ranges from 14 to 17°C (Table 3). It is recommended to keep drinking water at 20°C (Hosseinlou *et al*., 2013). This temperature hinders mesophilic pathogenic bacteria. Therefore, Nedjo drinking water is in the recommended range of temperature, which contributed to the poor growth of coliform bacteria (Table 2).

The electric conductivity (EC) of Nedjo town drinking water ranged from 218–393 µS/cm (Table 3). The highest EC was for the water sample collected from SR, and the lowest was for HH9, which were significantly different from each other at $\alpha = 0.05$. According to WHO (2008), the EC of drinking water should be less than 400 µS/cm. Therefore, based on EC, Nedjo town drinking water was in the acceptance range. However, the significant variation between the two sampling points could be related to the turbidity of the water, as shown in Table 3, because EC indicates the amount of TDS in the water (Yilmaz & Koc, 2014).

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 solutions (WHO, 2008). The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulphate, and nitrate anions. The TDS of Nedjo drinking water was in the range of 62.73 to 154 mg/L, the highest and lowest by HH1 and WW, respectively. According to WHO (2011), the optimum range for hardness (calcium and magnesium) in drinking water is 100–500 mg/L. Therefore, Nedjo drinking water at household levels was considered "poor" in mineral content (Islam *et al*., 2016) because the minerals are needed in the diet. In addition, the mineral will balance body ions and energy. Besides, the taste of water containing low minerals is sour or flat. On the other hand, water containing excess minerals tastes metallic, salty, earthy, etc. (Islam *et al*., 2017). Therefore, a significant deviation of the TDS level in drinking water from the standard values is unacceptable to consumers, not only because of taste but also due to dietary factors.

Table 3

The mean of Physical properties of Nedjo town drinking water between January and August 2019

SP	Physical Parameters					
	pH	T(^{0}C)	EC(μS/cm)	TDS(mg/L)	TSS(mg/L)	TURB(NTU)
SR	6.66±0.1^{ab}	17.6±0.1^{a}	393.2^{a}	195.83±0.1^{ab}	0.286^{b}	4.23^{a}
RES	8.13±0.1^{a}	17.6±0.1^{a}	375.4^{a}	193.2±0.2^{ab}	0.027c	1.42^{c}
HH1	7.78±0.1^{a}	14.76±0.1^{ab}	294.6^{ab}	162.73±0.1^{b}	1.027^{a}	2.5^{ab}
HH2	7.96±0.1^{a}	15.03±$^{0.1\ ab}$	286.9^{ab}	190.26±0.1^{ab}	0.032^{c}	1.31^{c}
HH3	7.23±0.1^{a}	16.26±0.1^{a}	279.7^{ab}	193.9±0.1^{ab}	0.04^{c}	1.59^{c}
HH4	7.93±0.1^{a}	13.5±0.1^{ab}	294.5^{ab}	191.2±0.1^{ab}	0.037^{c}	1.83^{c}
HH5	7.23±0.1^{a}	12.9±0.1^{b}	292.3^{ab}	195.5±0.1^{ab}	0.033^{c}	1.42^{c}
HH6	7.23±0.1^{a}	14.7±0.1^{ab}	276.9^{ab}	191.16±0.1^{ab}	0.143^{b}	1.4^{c}
HH7	7.36±0.1^{a}	14.83±0.1^{ab}	288.4^{ab}	191.03±0.1^{ab}	0.034^{c}	1.6^{c}
HH8	7.36±0.1^{a}	13.93±0.1^{ab}	220.4^{b}	190.63±0.1^{ab}	0.014^{c}	1.26^{c}
HH9	7.63±0.1^{a}	11.53±0.1^{b}	218.1^{b}	129.83±0.1^{c}	0.24^{b}	2.57^{ab}

Keys: Numbers indicated by the same letters across Colum are not significantly different from each other at α = 0.05. SR, sources; RES, reservoir; SP, sampling point; HH1 to 9, households labelled as sampling points one up to nine; T, temperature; EC, electrical conductivity; TDS, total dissolved solids; TSS, total suspended solids; TURB, turbidity

Total Suspended Solids (TSS), also known as non-filterable residues, are those solids (minerals and organic material) that remain trapped on a 1.2 μm filter (EPA, 1998). Suspended solids can enter groundwater through runoff from industrial, urban, or agricultural areas and reduce water clarity. In this test, Nedjo town drinking water showed a maximum TSS of 1.027 mg/L at the household level of HH1 (Table 2). This value is very low as compared to the TSS of spring water in Arba Minch (Amanial, 2015) and drinking water from different sources in the Jimma zone (Yasin et al., 215), which showed a maximum 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 silt, chemical precipitates, and organic particles (Rice et al., 2012). Turbidity reduces the clarity of the water. Sources of Nedjo drinking water showed the highest turbidity, with a maximum of 4.23 NTU at SR. The samples from households in HH1 and HH9 also showed 2.89 NTU and 2.57 NTU, respectively. According to WHO (2011), the turbidity of drinking water at the household level should be kept below 0.2 NTU. Therefore, Nedjo drinking water requires treatments to reduce factors that contribute to high turbidity levels.

Chemical water quality tests

The maximum concentrations for Fe^{+2} and Mn^{+2} at Nedjo drinking water were 0.22 mg/L and 1.04 mg/L, respectively. The recommended limits for Fe^{+2} and Mn^{+2} in drinking water are 0.3 mg/L and 0.05 mg/L, respectively (Seelig *et al*., 2005). When the level of Fe^{+2} exceeds the limit, water turns 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 (WHO, 2011). In addition, the maximum levels of nitrate, sulphate, and phosphates in the drinking water in Nedjo were 38 mg/L, 3.6 mg/L, and 0.86 mg/L, respectively (Table 4), which are below the upper limit established by WHO (2011). High levels of nitrate and sulphate in drinking water may induce "blue baby" syndrome (methemoglobinemia) and laxative effects, respectively.

Table-4

Mean of Chemical properties of Nedjo town drinking water between January and August 2019

SP	Chemical Parameters							
	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)
SR	0.22^{ab}	0.80^{ab}	0.3±0.1^{d}	BDL	0.30^{a}	0.74^{ab}	0.006^{c}	47.3±0.1^{a}
RES	0.176^{a}	0.60^{ab}	1.4±0.1^{c}	0.8±0.1^{bc}	0.64^{a}	0.64^{ab}	0.023^{b}	48.6±0.1^{a}
HH1	0.11^{a}	0.23^{ab}	1.0±0.1^{c}	1.4±0.1^{b}	0.77^{a}	1.19^{a}	0.012^{b}	34.3±0.1^{ab}
HH2	0.016^{b}	0.27^{ab}	17.1±0.1^{ab}	1.8±0.1^{b}	0.47^{a}	0.96^{a}	0.035^{b}	37.6±0.1^{ab}
HH3	0.04^{b}	1.04^{a}	1.06±0.1^{c}	3.6±0.1^{a}	0.86^{a}	1.0^{a}	0.019^{a}	37.6±0.1^{ab}
HH4	0.09^{b}	0.40^{ab}	20.5±0.1^{ab}	2.6±0.1^{ab}	0.59^{a}	0.57^{ab}	0.11^{ab}	34±0.1^{ab}
HH5	0.04^{b}	0.25^{ab}	38±0.1^{a}	2.6±0.1^{ab}	0.85^{a}	0.77^{ab}	0.067^{b}	33.3±0.1^{ab}
HH6	0.11^{ab}	0.95^{a}	28.0±0.1^{a}	3.6±0.1^{a}	0.63^{a}	0.99$^{d\ a}$	0.065^{b}	36.3±0.1^{ab}
HH7	0.09^{b}	1.02^{a}	25.83±0.1^{a}	0.8±0.1^{bc}	0.66^{a}	1.29^{a}	0.033^{b}	24.0±0.1^{a}
HH8	0.06^{b}	BDL	8.26±0.1^{b}	0.8±0.1^{bc}	0.54^{a}	0.91^{a}	0.13^{a}	35.3±0.1^{ab}
HH9	0.11^{ab}	0.34^{ab}	3.0±0.1^{bc}	0.8±0.1^{bc}	0.44^{a}	1.10^{a}	0.016^{b}	40.6±0.1^{ab}

Keys: Values designated by the different latter across columns indicated the absence of significant variation at $\alpha = 0.05$. SR, water from source; RES, water from reservoir; SP, sampling point; HH1 to 9, households labelled as sampling points one up to nine

The World Health Organisation (WHO, 2008) concluded that there is no nutritional basis for the regulation of phosphorus levels in US drinking water supplies. However, to control eutrophication, USEPA makes the following recommendations for total PO4 with P ≤ 0.025 mg/L for drinking water reservoirs (Fadiran *et al*., 2008). Therefore, the phosphate content of Nedjo drinking water is in the acceptable range recommended by WHO (2008). The levels of fluorine and chlorine in Nedjo drinking water samples range from 0.21–1.29 mg/L and ≤0.13 mg/L, respectively (Table 4). According to WHO (2011), the optimum levels of the two minerals in drinking water are 0.6 mg/L and 250 mg/L, respectively. Dental fluorosis develops when fluorine levels in water are too high, whereas tooth decay occurs when levels are too low. The excessive concentration of chlorine in drinking water gives a salty taste to the water that cannot quench thirst, but a lower concentration affects the treatment process. In general, according to WHO (2011), the chemical parameters tested for Nedjo drinking fit the standard except for the excessive amount of Mn and the insufficient amount of Cl compounds.

Correlations between bacteriological and physical parameters

Total coliforms were negatively correlated to the chemical parameters of the water, except for Fe^{+2} and TH. TC showed a positive and strong correlation (α = 0.01) with Fe^{+2} and a negative and strongly correlated correlation 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 Nedjo drinking water, 2019

Chemical parameters	Biological and Physical parameters						
	TC	pH	T	EC	TDS	TSS	Turb
Fe	.70**	-.42	-.49	-.30	-.54	.19	.72**
Mn	-.10	-.23	.28	-.15	-.33	-.17	-.10
NO3	-.517	.11	.18	.219	.17	-.36	-.51
SO4	-.43	.27	.41	.24	.28	-.17	-.46
PO4	-.55	.06	.54	-.10	-.08	.18	-.47
F	-.14	-.17	.10	-.23	-.12	.29	-.07
Cl	-.56*	.07	.26	.043	-.02	-.35	-.58*
TH	.03	-.63*	-.05	-.41	.08	.08	.12
TC	1	-.15	-.84**	-.17	-.10	.27	.98**

**. Correlation is significant at the 0.01 level (2-tailed);

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

pH was also strongly negatively correlated with TH, and TDS was positively correlated with NO_3^-, SO_4^{-2} and TH. Besides, TH was significantly positively correlated with PO_4^{-3}, F, and TH (Table 5). Similarly, previous research also showed a correlation between the biological and physicochemical properties of drinking water (Bhandari & Nayal, 2008).

Effect of sampling points and sampling seasons on Bacteriological and physicochemical parameters

Nedjo 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 points except for pH, temperature, and EC (Table 6). The effect of sampling points and their characteristics on microbiological parameters is indicated in WHO (2011).

Table-6

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

SV	Parameter (P-values)													
	TC	pH	T^o	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	*	*

Keys: **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; pH, EC, electrical conductivity; TDS, total dissolved solids; TSS, total suspended solids; TURB, turbidity.

Sampling time (seasons) also has 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 the physicochemical parameters of drinking water (Ngabirano *et al*., 2016).

CONCLUSION

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

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