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Assessment of Quality of drinking waterbased on the water quality index method in Hawassa Zuria Woreda, Sidama Regional State, Ethiopia

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Abstract

Background. Ethiopia is one of the Sub-Saharan African developing nations that encounters the majority of the usual difficulties in delivering water services to its inhabitants. Thus, 60–80% of the populace is afflicted by diseases that are waterborne or connected to water. This is partly due to the shortage of access to safe water distribution systems. This study was to conduct an Assessment on Quality of drinking water based on the water quality index method in Hawassa Zuria Woreda, Sidama Regional State, Ethiopia.

Methods. A total of twenty-three representative water samples were collected from different sources, such as two samples from the source borehole (BH), five samples from the reservoir, eight samples from storage (household containers), and eight samples from the taps. The Water Quality Index (WQI) tool was used to determine the overall condition of water quality with different physico-chemical parameters. To determine the p 0.05 significant differences in the mean values of the water quality measures at the various sampled sites and to observe the associations of variables, one-way ANOVA and correlation were used. To match the results of the heavy metal level with the WHO value, a t-test was used.

Results. Bacteriological (total coliform and fecal coliforms) and physicochemical parameters such as temperature, pH, Electric conductivity, Turbidity, TDS, Nitrate, Ammonia, phosphate, Free chlorine residual, Iron, Total hardness , Magnesium, Nitrite, fluoride and Analysis of heavy metals (Mn, Pb, Zn, Co, Cu, and Ni) was done to determine their appropriateness for drinking. The study's findings demonstrated that the majority of the criteria should have been within the WHO's safe drinking water guidelines and Ethiopia's drinking water standards. However, temperature, electric conductivity, ammonia, phosphate, fluoride, lead, and nickel were among the physicochemical characteristics that in different sampling sites exceeded these safe limits. The values of temperature, turbidity and nitrate were significantly differing from the supplied source to household storage. However, other parameters showed no significant change from source to storage. The WQI values of the analyzed water samples indicate that 73.9% of all analyzed samples were excellent and 26.1% were good. The mean HPI and HEI, respectively, were 75.72 and 1.47. The average HPI score was below the threshold of 100. The average metal concentrations in drinking water were discovered to be distributed in the following order: Zn>Ni>Co>Cu>Mn>Fe>Pb. A sample t-test showed that there was an extremely significant difference (p0.01) between the GUIDELINE values and metals other than lead. The Pb/Zn elemental pair is significantly linked with each other (r = 0.524, P 0.05), in contrast to the other elemental pairs, which do not significantly correlate with one another. Pairs of Pb/turbidity are associated with one another (r = 0.715, P 0.01), according to element and physicochemical associations. Similarly, there is a significant correlation between Cu/turbidity and Cu/pH (r = -0.522, P 0.01). The relationship between EC and turbidity is also substantially correlated (r = 0.567, P 0.05).

Conclusion. This research strongly suggests that drinking water from heavy metal-contaminated sites should be outlawed and that lead and nickel removal should receive special attention from the appropriate authorities.

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Introduction

Water is essential to sustain life, and a satisfactory (adequate, safe, and accessible) supply of drinking water should be available to all (Okorafor et al., 2012, Mboto et al., 2019). Improving access to safe drinking water may result in tangible benefits to health. So that, every effort should be made to achieve drinking water that is as safe as practicable (WHO, 2017). The availability and accessibility of good water quality is crucial for both social and economic growth, as well as for ensuring public health, environmental protection, and sustainable development (WHO, 2008).

Water is one among the foremost, important, and most precious natural resources. Without it, there would be no life on earth. It is essential to the survival of civilization. However, the majority of people in the globe, mostly in Africa and Asia, do not have access to better water supplies or sanitation services (WHO/UNICEF, 2017). Sub-Saharan African countries are at the front of the water scarcity problem, one among which is Ethiopia, despite the fact that the country has abundant groundwater, major lakes, and large volumes of rainfall (WHO and UNICEF, 2019).

Ethiopia has the lowest water supply and sanitation coverage (WHO and UNICEF, 2019). Ethiopia is one of the developing countries in Sub-Saharan Africa, facing most of the common challenges in providing water services to its citizens. According to data from WHO and UNICEF estimated in 2015, only 11% of the total population had access to improved water supply, 59% had access to unimproved sanitation (WHO/UNICEF, 2017). Safely managed beverage services are improved sources accessible to the premises, available when needed, and free from fecal and specified chemical contamination (WHO and UNICEF, 2019). According to report by the Central Statistical Agency of Ethiopia (2017), nationally 13 percent of the population is considered using safely managed services (CSA, 2017).

By definition, heavy metals are metallic elements with large relative atomic masses and densities that are at least five times greater than those of water. They are bio-accumulative, which means they move up the food chain to reach people, and stable, which means they cannot be metabolised by the body. They are extremely toxic even at very low concentrations, and they can have negative impacts (Mohiuddin et al., 2011). Heavy metals are among the foremost common environmental pollutants, and their occurrence in waters and biota indicates the presence of natural or anthropogenic sources (Mohiuddin et al., 2011).Heavy metals tend to accumulate in human organs and nervous system and interfere with their normal functions (Jaishankar et al., 2014). Heavy metals that cause health issues, such as manganese, lead (Pb), zinc (Zn), cobalt, copper (Cu), and nickel (Ni), have drawn a lot of attention in recent years (WHO, 2017).

Quite a number of studies have been conducted in the whole world to determine the concentration of heavy metals in water samples (Tesfamariam and Younis, 2016, Shigut et al., 2016, Sage et al., 2018, Ododo, 2019). The heavy metals like Cd and Pb are toxic even in very small amounts. Heavy metals like Co, Cr, Cu, Fe, Mn, Ni, and Zn are required by the human body in small amounts, but can also be toxic at large levels (Ododo, 2019). Although individual heavy metal exhibit specific toxic effects on human beings, damage to the kidney, liver, lung, blood cells, mental and central nervous systems, and other vital organs are general toxicities associated with Cd, Co, Cr, Cu, Fe, Ni, Mn, Pb, and Zn. Zn, As, Cu, Cd, and Pb are among these heavy metals that are more toxic than other metals and are found throughout the earth's surface (Haftu and Sathishkumar, 2020). Moreover, long-term exposure to some of them may cause cancer (Marmiroli and Maestri, 2008). These toxicities can result from any of the heavy metals if it is present in excess amount in drinking water. These harmful heavy metals have a propensity to build up in the body and may cause long-term harm (Jamshaid et al., 2018). The beverage must be free from these toxic substances. So, it is vital that the drinking water should be evaluated at a regular time interval to ensure its good quality.

Approximately 75% of patients, according to a report from the Hawassa Zuria Health Office (2019G.C), have water-borne illnesses like kidney and liver damage, stomachache, diarrhea, vomiting, high fever, and gastrointestinal discomfort. According to the researcher's knowledge, there hasn't been any study on drinking water quality assessment using water quality index.. Therefore, the main aim of this study was to investigate the levels of heavy metals such as Mn, Pb, Zn, Co, Cu and Ni; (2) To assess the physicochemical parameters of drinking water (3) To assess the overall water quality with different physico-chemical parameters based on Water Quality Index (WQI) tool, (4) To assess the water quality using the heavy metal pollution index, heavy metal evaluation index models and (5) To evaluate the Bacteriological quality of Drinking Water in Hawassa Zuria Woreda.

Materials & Methods

Description of the Study Area

In Hawassa Zuria Woreda, Ethiopia, a rural area was chosen for this research. The Woreda is located between 38° 15′ 39″ and 38° 25′ 43″ E and 07° 01′ 54″ to 07° 50′ 36″ N. Dore Bafano, which is 21 kilometres southwest of Hawassa, serves as the regional centre of Hawassa zuria Woreda. The Woreda is bordering Tula town within the east, Lake Hawassa within the north, the Oromia Region within the west, and therefore the Boricha district to the south. The elevation ranges from 1700 m to 1850 m asl. There are 23 peasant governments in the woreda. The most widely grown grain in the woreda is maize. The Woreda had a total population of 160180 in 2013E.C, of which 81692 (51%) were female and 78488 (49%) were males. 4 state health facilities, 23 health posts, 1 primary hospital, and 8 private clinics are all present in the woreda.

The study region, Hawassa Zuria Wereda, has average annual maximum and minimum temperatures of 30 °C and 17 °C, respectively, and an average annual rainfall of 1015 mm. Two agroecological situations exist, with 80% "kola" (lowland) and 20% "woyna dega" (highland) (midland). According to the information from the Hawassa Zuria woreda water office, there were improved drinking water sources (two boreholes and one protected spring). In the study area, the water source for drinking is obtained from the two boreholes. The borehole water is collected and then stored in large reservoirs located in Betemengist Area. The treatment process being applied is chlorination alone.

Water Points Selection procedure

Only 20% of the 23 rural Kebele Administrations in Hawassa Zuria Woreda were chosen for this research, primarily due to the availability of various drinking water sources. Drinking water quality analyses usually cover the sources, the reservoir (disinfection point), tap (point of use), and the storage container. Consequently, water samples were obtained from the reservoir's source(R) and borehole (BH). Additionally, water samples were taken using clean and/or sterilized containers for heavy metal, bacteriological, and physicochemical studies from household containers (H) and piped water at specific individual taps (Figure 1). Accordingly, five Kebeles were selected for this purpose were Dore Bafano, Galo Argisa, Jarra Dado kebele and Rukessa Suke from ''Kolla'' and Umbulo Kajima kebele from ''Woindega'' agro-climatic zonation(Table 1). Finally, probability proportional sampling techniques were used to select the households from each sampled kebeles.

Sampling size for water quality

Twenty-three typical water samples were collected from two samples from the source borehole (BH), five samples from the reservoir, eight samples from the storage (home containers), and eight samples from the taps. Based on the number of people supplied, the distribution system's minimum sampling frequency for drinking water was established (ESA, 2013) (Table 2).

Water Sample Collection and storage

For each sampling site, triplicate samples were collected for different parameters from sampled water supply schemes. Two hundred fifty milliliters of water sample was collected aseptically in sterilized bottles from the boreholes, reservoir, tap water, and households' containers for bacteriological. After collection, the samples were preserved for bacteriological analysis (collected in triplicate); while the second set of samples from the same sources for chemical analyses were collected in acid-washed one-liter polyethylene bottles. The third type of samples were acidified and preserved with HNO3 for ion and heavy metal analysis from the boreholes, reservoir, and tap water. Water sampling and preservation techniques followed the standard preservation (APHA, 1999). The samples were collected between 7:00 and 8:00 in the morning. All chosen physicochemical parameters were examined following the collection of samples from each sampling location, both in the lab and in the field. Water samples were collected, and a cooler comprising ice packs and freezer packs was used to transport them to the lab. In order to prevent the death or proliferation of organisms in the sample, bacteriological tests were carried out within 6 hours following sample collection (WHO, 2006, Monica, 2000)

The samples acquired for the heavy metals assay were preserved right away with concentrated HNO3 to a pH value of 1.5. (APHA, 1999). In order to prevent contamination and the effects of light and temperature, these sample bottles were sealed and kept in a dark environment at a constant temperature range of 4-10 0C for the duration of the 48-hour physico-chemical examination. The collection, preparation, and preservation procedures followed a similar pattern to those described in earlier investigations (Shigut et al., 2016, Ododo, 2019, Sitotaw, and Nigus, 2021).Physico-chemical parameters were done in the school of Bio-systems and Environmental Engineering, bacteriological quality analysis at Environmental Health Department and Heavy metal were analyzed at Department of chemistry, Hawassa University.

Water Sample Analysis Methods

Onsite analysis of the physico-chemical parameters were carried out at the site of sample collection following the standard protocols and methods of American Public Health Organization (APHA, 1999). The pH, temperature, electrical conductivity, and turbidity were measured using multiparameter (AD8000, Adwa).

Nitrate, Ammonia, Phosphate, Free Chloride, Iron, Total Hardness, Magnesium, Nitrite, and Fluoride were measured using the DR 6000 spectrophotometer, keeping track of their reaction times, and analysing the analytical chemicals in accordance with established procedures (APHA, 2017).

The Chemistry Laboratory at Hawassa University used flame atomic absorption spectroscopy (Buck Scientific, Model 210VGP AAS, USA) equipped with a deuterium background corrector and an air acetylene flame atomizer to ascertain the concentration of the selected metals (Mn, Pb, Zn, Co, Cu, and Ni). Stock standard solutions (Buck Scientific purographics calibration standards, USA) containing 1000 mg/L of the metals Mn, Pb, Zn, Co, Cu, and Ni were used to create calibration standards for each metal..

Instrument Operating Conditions and Calibration

The flame atomic absorption spectrophotometer (Buck Scientific Purographics Calibration Standards, USA) was used to analyse a total of six metals for fifteen samples after the parameters for burner and lamp alignment, slit width, and wavelength adjustment were optimised for the instrument's maximum signal intensity. The corresponding hollow cathode lamp for each metal was put into the atomic absorption spectrophotometer, and the solution was subsequently aspirated into the flame one at a time. The instrument's absorption mode was used to conduct analyses on all six metals (Mn, Pb, Zn, Co, Cu, and Ni). For each sample, three duplicate assessments were made. Six digested blank solutions of water samples were used to determine the elements using the same chemical method (Table 3).

For the calibration of the instrument, an intermediate standard solution containing 10 mg/L was produced in a 100 mL volumetric flask from the standard stock solution (Buck Scientific Purographics Calibration Standards, USA), which had 1000 mg/L of each metal. The intermediate standards were then diluted with distilled deionized water to produce four working standards of each pertinent metal for calibration purposes. In order to minimise memory interference, the uptake system was flushed with a clean blank (deionized water). In order to calibrate the instrument, four operational benchmarks were used. The calibration curve's correlation coefficients for all of the metals were higher than or equal to 0.997, ensuring the linearity of the instrument's response to each individual analyte.

Heavy Metal Pollution index (HPI)

The HPI is used to assess the cumulative impact of each heavy metal on the total water quality. It was developed in two stages and rates the combined impact of each heavy metal on the overall quality of water. By first creating a scoring scale with weights for each parameter that is chosen, and then by choosing the pollution parameter that will serve as the index's foundation. The unit weightage (Wi) was used in the current model as a value that was inversely proportional to the suggested standard (Si) for the associated parameters. The WHO's (2017) permissible value for drinking water was used in this research. While measurements of the elements Mn, Pb, Zn, Fe, Cu, and Ni were made for use in the model index. The formula below was used to compute the HPI as described by (Mohan et al., 1996; Chiamsathit et al. 2020; Regina et al.2021).

$$HPI = \sum_{i=1}^{i=n} (Qi \times Wi) \div \sum_{i=1}^{i=n} Wi \qquad \text{Eq. (1)}$$

Where

Qi is the sub-index of the ith parameter,

Wi is the unit weight of the ith parameter and

n is the number of parameters considered; the subindex (Qi) of the parameter is

$$Qi = \frac{Vi}{Si} \times 100 \qquad \text{Eq. (2)}$$

Where

V_i is the monitored value of metal of ith parameter and Is the standard value

In this study, the index was intended for drinking water, and the permissible or critical pollution index value for drinking water is 100 (Mohan et al. 1996**).**

Heavy metal evaluation index (HEI)

The HEI is calculated as shown in Eq. (3) and provides, like the HPI, a general assessment of the water sample's quality regarding heavy metals.

$$\text{HEI} = \sum_{i=1}^{n} Hc \div Hmax \qquad \text{Eq. (3)}$$

Where Hc and Hmac are the measured value and maximum admissible concentration of the ith parameter, respectively (Onyenmechi et al.2020).In this study, the hmac was used as the same as the GUIDELINE value for each metal.

The classification scheme for HEI by Onyenmechi et al. (2020)., which categorizes water into low, medium, and high using multiples of the mean index values, was used. In this study, the cut-off values were: < 7.5, low; 7.5 -15, medium; and > 15, high.

Water Quality Index (WQI)

WQI is defined as a rating reflecting the composite influence of various water quality parameters on the general quality of water. WQI was used to get a comprehensive picture of the overall quality of water. The WQI is frequently used for the detection and evaluation of pollution, and it may be viewed as a composite influence of multiple quality metrics on overall water quality. (Adamou et al., 2020). The World Health Organization's criteria and recommendations were used to evaluate the water's quality and degree of pollution. (WHO, 2011). When WQI is utilized, the importance of the examined parameters is more clear. Using the methodology described in, the WQI was determined. (Batabyal and Chakraborty, 2015, Adamou et al., 2020). The calculation of the WQI included 11 important parameters (pH, EC, Turbidity, NO_3^-, NH_3, Po_4^{-3}, Cl^- Fe^{+2}, total hardeness, Mg^{+2}, No_2^-), as well as their WHO standards (WHO, 2011).

The WQI was calculated using the following formula:

$$\text{WQI} = \sum qn\, Wn \div \sum Wn \qquad \text{Eq. (4)}$$

$$qn = \frac{vn - Vid}{Sn - Vid} x100 \qquad \text{Eq. (5)}$$

$$Wn = \frac{k}{Sn} \qquad \text{Eq. (6)}$$

$$k = 1 \div \left(\frac{1}{\sum Sn}\right) \qquad \text{Eq. (7)}$$

Where

- qn: quality of nth water quality parameter
- Wn: Unit weight of nth water quality parameter
- Sn: permissible value of the nth water quality parameter
- Vn: Estimated value of nth water quality parameter at a given sample location
- Vid: ideal value for the nth parameter in pure water (0 for all other parameters except pH (7)
- k: Constant of proportionality.

After using WQI calculation, WQI developed by brown et.al. (1972), the quality was determined by using the following scale: excellent (0-25), Good (26-50), Poor (51-75), Very poor (76-100) and unfit for consumption (>100).

Microbial Analyses

Membrane filtration was used to analyse samples for bacteriological factors in order to assess the level of contamination. (WHO, 2008, APHA, 1999).To check for the existence of total coliforms, all samples were examined. (TC). The growth pads were frequently inserted into the bottom of Petri plates using a sterilised pad dispenser, which caused the growth pads to become saturated with Lauryl Sulphate Broth. Using a membrane filter (0.45 m) and a vacuum filtering apparatus, a 100 ml water sample was filtered. The filters were then transferred to an absorbent pad that had been saturated with broth. Prior to incubation, the Petri plates were incubated at 37°C for 4 hours to resuscitate coliforms that were under physiological stress. Colonies were counted and documented after plates for total coliform and thermo-tolerant coliform counts were incubated at 37°C and 44°C, respectively, for 24 hours.

Data Analysis

Microsoft Excel and Minitab version 16 software were used for the study. (MS Excel). ANOVA was used to find statistically significant differences in the average values of the water quality parameters at the different sampled sites at the 0.05 level of significance. Correlation was also used to see the statistical significance relationship between the physico-chemical parameters. To match the results of the heavy metal level with the WHO value, a t-test was used. As indicated by the risk classification for thermo tolerant coliforms of water supply, water samples were also divided into various risk categories (Tadess, 2014). Information was displayed using tables, figures, etc. To explain the data, frequency distribution and percentage calculations were made.

Results

Physico-chemical Parameters

A total of twenty-three water samples were analyzed from source, reservoirs, tap water, and end users (household containers) as shown in Table 4. The mean temperature of the water samples ranged from 20.53 to 25.5o C. The average temperature values of water sources were found to be significantly lower ($p < 0.05$) than those of reservoirs, tap water, and end users. However, the differences in the mean temperature of the reservoir, tap water and point of sampled sites were not significant at the $p < 0.05$ significant level (Table 4).

Regarding the pH of the water samples, they were found to fall between pH 6.689-7.014 recorded from source and from end users, respectively. The differences in the mean pH of the source, storage, and point of sampled sites were not significant at the $p < 0.05$ significant level.

In the present study, the highest EC (658.41µS/cm) was recorded from end users (Household Containers) whereas the lowest conductivity was recorded from the sample obtained from Reservoir (619µS/cm) and Tap water (622.25µS/cm). Nevertheless, the differences in the mean EC of the source, reservoirs, tap water, and households' container were not significant at $p \leq 0.05$ significant level.

The end consumers' turbidity was the lowest, while the source's turbidity was the greatest. In comparison to reservoirs, tap water, and end consumers, water sources were found to have considerably higher average turbidity levels (p 0.05). However, there was no statistically significant difference in the mean turbidity of the reservoir, tap water, and point of sampled sites at the p 0.05 significant level.

The behaviour of groundwater's salinity is revealed by total dissolved solids. Total dissolved solids (TDS) measure the amount of chemical compounds dissolved in water; at levels above 1500 mg/l (the Maximum Permissible Level), these compounds reduce palatability and may generate an unpleasant taste (WHO, 2011). TDS levels in the study's end users and reservoirs ranged from 371.4 mg/L to 395.1 mg/L, respectively.

The levels of nitrate in the water samples from source, reservoir, tap water, and end users were 1.033 mg/l,1.693mg/l, 1.724mg.l and 2.12mg/l respectively. The levels of concentrations in end-users were significantly higher than source, Nevertheless, there were no variations between end-users, tap water and reservoir in nitrate concentrations. The results also revealed that the average phosphates were 0.583mg/l, 0.845mg/l, 0.598mg/l, and 0.761mg/l for the source, reservoir, Tap water and And-users (household container) respectively (Table 5).

The result of the water samples analysis shows that the concentrations of residual free chlorine were 0.21mg/l, 0.26mg/l, 0.23 mg/l, and 0.198mg/l for the source, reservoir, Tap water and And-users (household container) respectively.

In the present study, the highest iron content was recorded in the household containers (0.056mg/l) and the lowest was recorded in the source (0.005mg/l). There was no variation in the mean values of Iron in the sampled sites from the source to end users.

The average total hardness as measured by $CaCO_3$ was 67.3 mg/l, 46.0 mg/l, 55.45 mg/l, and 53.66 mg/l, respectively, for the source, reservoir, tap water, and domestic container. The one-way analysis of variance (ANOVA) test revealed that at p 0.05 significant levels, there were no significant variations in the mean values of overall hardness across the various sampling sites.

According to the results of the laboratory testing, the mean magnesium concentrations in the source, reservoir, tap water, and residential container were 1.79 mg/L, 1.53 mg/L, 1.847 mg/L, and 1.903 mg/L, respectively. The mean magnesium readings at the different sampling sites did not differ significantly at p0.05 significant levels. Drinking water with fluoride levels between 0.7 and 1.2 mg/L will prevent dental caries. The water samples used in the current investigation had fluoride levels ranging from 1.25 mg/l (Dore Bafano Reservoir) to 4.5 mg/l. (Gamato borehole).

Correlation Matrix of the Physico-Chemical Parameters

The results of a pairwise Pearson correlation study between various water quality parameters revealed some intriguing correlations. Temperature, TDS, turbidity, electrical conductivity, total hardness, pH, nitrite, magnesium, iron, and nitrate were all determined, as well as the association coefficient (r). The correlation matrix revealed a poor link between pH and EC (r = -0.542/1.000, p 0.01) and no other physicochemical parameters had significant correlations at P 0.05 or 0.01. Turbidity (r = 0.422/1.00, p 0.05), TDS (r=0.99/1.00, p 0.01), Total Hardness (r=0.688/1.00, p 0.01), and Magnesium (r=0.663/1.00, p 0.01) all had favourable correlations with electric conductivity.Similar to TDS, total hardness (r=0.484/1.00 P 0.05) and turbidity (r=0.42/1.00 P 0.01) all showed favourable correlations.TDS also had favourable correlations with total hardness and magnesium (r=0.668/1.00 P 0.01 and r=0.663/1.00 P 0.01, respectively). Nitrate and iron had an association coefficient (r) of (r=0.535/1.00, P 0.01), which was significant (Table 6).

Water Quality Index (WQI) of different waters

In Table 7, the WQI score and water type of each sample are listed. The WQI values were between 1.05 to 43.71. Turbidity, Fluoride, Ammonia, Lead, Nickel, and Electric Conductivity were the factors that had the biggest effects on these numbers. The WQI scores for the water samples showed that 26.1% of the samples were good and 73.9% of the samples overall were excellent (Table 7).

The concentration of Heavy Metals in drinking water

According to Table 8's findings, copper, nickel, manganese, zinc, and cobalt were found in the majority of the water samples. Lead was only found in one of the three water samples, but copper and zinc were found in every sample.

Manganese was found in 9 samples of potable water, while it was undetectable in 6 other samples. (Figure 2).The amount of manganese varied from ND to 0.05650mg/l. The highest concentration of Mn was found at (Galo tap 2), which was followed by (Betemengist pond 2), 0.03931mg/L, and (Rukessa tap water), which had a concentration of 0.03275mg/L, while the lowest concentration was found at (Dore tap 1), which had 0.00303mg/L.

Lead was found in 3 samples, despite the number in 12 samples being below the detection threshold. The mean lead content was 0.0077 mg/l, with a range of ND - 0.05567 mg L-1. More than three-quarters of the samples fall within the BDL band. The water sample from the Umbulo faucet contained the highest amount of lead (0.05567 mg/L), followed by that from the Boqo borehole (0.0483 mg/L), and the Gamato borehole (0.01167 mg/L).

15 samples of potable water contained zinc. (Figure 4). Zinc levels varied from 0.01633 mg/l to 0.9499 mg/l. Zn amounts were the highest (0.9499 mg/L) in the Dore reservoir.The samples with the greatest and lowest zinc contents in the current analysis were Galo tap 2 (0.9499 mg/l) and Dore tap 1 (0.01633 mg/l), respectively.

Cobalt was only found in 5 samples of potable water, despite the fact that 10 of the samples were below the detection threshold. Cobalt concentrations in the study varied from ND to 0.06767mg/L.Thirteen samples of potable water contained copper, but only one of those samples had copper concentrations below the detection threshold. (Figure 2). Copper levels varied from 0.0051 mg/l to 0.04 mg/l. The Umbulo reservoir had the lowest content of copper (0.00833 mg/L), while Jara Dado Tap 1 had the highest concentration (0.04 mg/L).

In this research, nickel was found in 6 samples of drinking water, while 9 samples had no nickel concentration. (Figure 2). Nickel concentration varied from ND to 0.0937 mg/L, with significant concentrations found in the Betemengist reservoir 2 and Umbulo reservoir, respectively, at 0.0913 mg/L and 0.0937 mg/L, respectively (Table 8).

Thirteen samples of potable water contained iron, but only two of those samples' concentrations were below the detection threshold. (Figure 2). (Umbulo reservoir) had the highest percentage of iron, and samples in (Rukesa tap). The average metal concentrations in drinking water were discovered to be distributed in the following order: Zn>Ni>Co>Cu>Mn>Fe>Pb.

Pearson Correlation Coefficient Matrix for Trace Elements and Physico-Chemical Characteristics

Lead, zinc, turbidity, copper, and EC were all correlated with one another using the correlation coefficient (r). This demonstrates that the elemental pair Pb/Zn (r = 0.524, P 0.05) is substantially correlated with each other, whereas the other elemental pairs do not. Pairs of pb/turbidity are associated with one another (r = 0.715, P 0.01) according to element and physicochemical associations. Similarly, there is a significant correlation between Cu/turbidity and Cu/pH (r = -0.522, P 0.01). Similar to how EC/turbidity (r = 0.567, P 0.05) is substantially correlated with each other, the other variables are not. The assessment indices' Pearson correlation revealed a significant positive link between the HPI and HEI (r = 0.947; P 0.01). Lead and all heavy metal pollution measures showed a strong and positive correlation (HPI, r = 0.960; HEI, r = 0.961) (P 0.01) (Table 9).

One sample t-test comparing the means of the parameters with WHO parametric values

A highly significant difference (p 0.01) was found between the manganese concentration found in the samples gathered and the WHO's recommended values. When compared to the number recommended by the WHO, the lead concentration was not significant. Comparing the concentration of Zn to the WHO-recommended value revealed a significant disparity. (2017). Similar to this, an extremely significant difference (p0.01) between the samples' Copper, nickel, and iron drinking water concentrations and the recommended values was observed (Table 10).

Heavy Metal Pollution Index (HPI)

The mean HPI and HEI, as shown in Table 11, were 75.72 and 1.47, respectively. The average HPI score was below the threshold of 100. With 50% of the borehole water and 25% of the tap water having HPI values above the crucial value of 100, 20% of the water samples had HPI values that were higher than this threshold. 100% of the water samples were categorised as minimal contamination based on HEI values (Table 11).

Bacteriological quality of drinking water

In this research, total coliforms were detected in 43.48% (10/23) of the drinking water samples. (TC) When comparing each sampling location, 50% (4/8) of tap water samples and 75% (4/8) of domestic container samples tested positive for TC. Water samples collected from household containers had the highest mean TC counts (190 CFU/100 mL), whereas samples taken from the source and reservoir had the lowest mean TC counts (0 CFU/100 mL)(Table 12).

Thirty-four percent (7/23) of the water samples tested positive for faecal coliforms (FC), which means they did not meet Ethiopian or WHO criteria. Of these, 62.5% (5/8) of the water samples from domestic containers and tap water, respectively, were positive for FC. Water samples taken from the tap were classified by Tadesse (2014) as low-risk, while samples taken from household containers were classified as high-risk, and samples taken from the source and reservoir were classified as no-risk. This categorization was based on mean counts of faecal coliforms (Table 12).

Discussion

Manganese concentration in this research ranged from ND to 0.05650mg/l.The manganese concentrations were less than the WHO standard's permissible maximum (0.1 mg/l). (WHO, 2017). The study's manganese concentration was higher than that of a prior one that was conducted in Ethiopia and published by (Kassegne and Leta, 2020, Gebresilasie et al., 2021). However, Muzaffarabad's ranged from 0.031 to 0.246mg/L and Rawalakot's ranged from 0.54 to 4.73mg/L (Javaid et al., 2008). (Ali et al., 2019).In humans, higher levels of manganese can cause serious nervous system disorders, and in the worst cases, long-term exposure can have a permanent neurological impact with symptoms similar to "Parkinson's disease." Paralysis agitans symptoms include weakness, shaking, slurred speech, anxiousness, sadness, amnesia, and frequent urination. (Jamshaid et al., 2018). Manganese in potable water has the potential to cause deposits to build up in the distribution system. Manganese concentrations of 0.05 mg/L or less can typically be attained in drinking water through oxidation and filtering.

The mean lead content was 0.0077 mg/l, with a range of ND - 0.05567 mg L-1. Water from the Umbulo tap had a lead concentration of up to 0.05567 mg/L, which was greater than the permitted limit of 0.01 mg/L. (WHO, 2017). Gamato BH, Boqo BH, and Umbulo water sampling stations had higher lead concentrations, measuring 0.01167 mg/L, 0.04833 mg/L, and 0.05567 mg/L, respectively. Lead concentrations in the study region were found to be higher than those reported by (0.0003 to 0.0025mg/L). (Rahmanian et al., 2015).but less than the levels recorded by Ali et al. (2019) for Muzaffarabad (0.029–0.665mg/L) and the Asgede Tsimbila District (0.008–1.10 mg/L) (Haftu and Sathishkumar, 2020). The research area's widespread agricultural practices, domestic sewage (plumbing), and water distribution system piping may be to blame for the highest concentration. Long-term exposure to lead in drinking water at levels higher than 0.01 has negative effects on the central nervous system, blood cells, and may induce brain damage. (Garza et al., 2006, Mansour, 2014). Common side effects of this damage include memory and focus issues, high vital signs, hearing issues, headaches, slowed growth, reproductive issues in both men and women, digestive issues, and muscle and joint discomfort. (Sankhla et al., 2016). Children are the most vulnerable to Pb toxicity, which can result in behavioural issues, cognitive issues, and anaemia.

The samples with the highest and lowest zinc contents in the current analysis—Galo tap 2 with a concentration of 0.9499 mg/L and Dore tap 1 with a concentration of 0.01633 mg/L, respectively—were both found to be below the ESA standards. (2013). As a result, these areas' drinking water had zinc contents that were lower than the permitted level (3 mg/L). (WHO, 2017). When compared to Rawalakot's 0.56 to 2.69 mg/L (Javaid et al., 2008), 0.050.405 mg/L (Ali et al., 2019), and Asgede Tsimbila District, Tigray's 0.785 to 5.32 mg/L, the Zn concentration found in our research ranged from 0.01633 mg/l to 0.9499 mg/L. (Haftu and Sathishkumar, 2020). Due to its impact on healthy bone formation and growth, zinc is a significant heavy metal that is essential to many organisms' metabolic and physiological processes. However, greater Zn concentrations are not recommended because they can poison humans and produce opalescence in alkaline waters and an unpleasant taste in foods(Haftu and Sathishkumar, 2020). The recommended dietary allowance for adult males is 15 mg/day, for adult women is 12 mg/day, for infants and toddlers it is 5 mg/day, and for adolescents it is 10 mg/day. The average daily intake of zinc is between 5 and 22 mg(Elinder et al., 1986).

Cobalt concentrations in the current research ranged from ND to 0.06767 mg/L, which were higher than those reported by(Solana et al., 2020). Cobalt is rarely found in potable water, but when it is, the concentrations range from 0.0001 to 0.005 mg/L. (ATSDR, 2004).Cobalt ions biochemically replace zinc ions, causing high blood pressure, kidney damage, and diseases of the Itai-itai variety by binding to the enzymes. (Rajappa et al., 2010).

The Umbulo reservoir had the lowest (0.00833 mg/L concentration) while Jara Dado Tap 1 had the highest (0.04 mg/L) copper values. The results were superior to those of other studies done in related fields. (Khan et al., 2015, Rahmanian et al., 2015, Gebresilasie et al., 2021). For the creation of haemoglobin and enzymes, copper is a crucial component.

Nickel concentration ranged from ND to 0.0937 mg/L, with high concentrations of 0.0913 mg/L in the Umbulo reservoir and 0.0937 mg/L in the Betemengist reservoir 2, respectively. The result of this study's investigation in the Umbulo reservoir was higher than the international standards maximum (0.07 mg/L). (WHO, 2017). Ni concentrations were higher in the study region than were previously reported by (Idrissa et al., 2020). Untreated urban sewage may be the cause of these increased concentrations in the water. High doses of Ni compounds can lead to serious illnesses like heart issues. Leaching from metals that come into contact with drinkable water is the main cause of nickel contamination in drinking water.

Iron concentrations in the samples ranged from 0.0 to 0.4 mg/L; the samples from the Umbulo reservoir and the Rukesa tap had the highest concentrations of iron, respectively. Iron is a common element in the earth's crust, although it is typically present in low concentrations in natural water (Ali et al., 2019). The formation of ferric precipitates makes drinking water objectionable.

Use the Pearson's correlation (r) formula to find the correlation between at least two continuous factors. The value of a Pearson's correlation might be between 0.00 (no link) to 1.00. (perfect correlation).More specifically, parameters with $r > 0.7$ are considered strongly linked, whereas those with r between 0.5 and 0.7 are considered moderately correlated (Helena et al., 2000).

The assessment indices' Pearson correlation revealed a significant positive link between the HPI and HEI ($r = 0.947$; P 0.01). All heavy metal pollution indices had a significant and positive correlation with lead (P 0.01) (HEI, $r = 0.961$; HPI, $r = 0.960$). The two pollution indices (HPI and HEI) and Pb have a strong positive correlation, suggesting that Pb pollution is the main cause of drinking water contamination in the study region. Therefore, compared to all other metals examined, Pb substantially increased the heavy metal load in the water samples. It was also to blame for the high contamination index scores that were found for some of the local water sources.

One sample t-test result showed that there was an extremely significant difference (p0.01) between the manganese concentrations measured in the collected samples and the WHO guideline values. When compared to the number recommended by the WHO, the lead concentration was not significant. Comparing the concentration of Zn to the WHO-recommended value revealed a significant disparity. (2017). Similar to this, there was an extremely significant difference (p0.01) between the samples' concentrations of copper, nickel, and iron compared to the recommended levels for drinking water.The values of the water quality indicator (WQI) ranged from 1.05 to 43.71. Turbidity, Fluoride, Ammonia, Lead, Nickel, and Electric Conductivity were the factors that had the biggest effects on these numbers. The WQI values for the water samples showed that 26.1% of the samples were good and 73.9% of the samples were outstanding. When the quality of the water is excellent or decent, it is preserved. Water of excellent quality does not present a threat of deterioration, and when the quality is acceptable, it is minimal (CCME, 2001).

The study area's mean HPI was measured at 75.72. The findings of Eldaw et al. (2020), Mirza et al. (2020), and Maskooni et al. are consistent with the HPI results in this research. (2020). In contrast, Regina et al. (2021) and Boateng et al. (2015) reported that underground water from Ghana's southwest coast and Ejisu-Juaben Municipality, respectively, had HPI values higher than 100.

In this investigation, total coliform (TC) levels in 43.48% of the drinking water samples were higher above the WHO guideline and Ethiopian criteria for drinking water quality (ESA 2013; WHO,2017). The prevalence of total coliforms in the present study was comparable with a study done in Adama town (Oromia region, Ethiopia) showing that 44.2% of the drinking water were positive for total coli form (Temesgen and Hameed, 2015) and comparable with a study conducted in Fiche (Oromia region, Ethiopia) which reported 36.47% samples were positive for TC(Sebsibe et al., 2021). However, this finding is less than studies done in Wegeda town (northwest Ethiopia) reported that the prevalence of positive total coliform was found to be 94.16%(Sitotaw et al., 2021), a study done in Kobo town (northern, Ethiopia) reported 95.8% of the drinking water samples were positive for total coliforms (TC) (Sitotaw and Nigus, 2021) and TC contamination rate of 100% by Duressa et al. (2019) in Nekemte town (western Ethiopia).This discrepancy might be due to the difference in the season where the study was conducted and type of water sources used.

The outcome showed that 30.43% of the water samples tested positive for faecal coliforms (FC), and as a result did not adhere to Ethiopian norms and WHO recommendations of zero FC per 100 ml. The findings of the present study were in agreement with previously reported results in Wegera district (Northwest Ethiopia) (Feleke et al., 2018), in Boloso Soro woreda (southern, Ethiopia) (Gizachew et al., 2020), in Ayetoro Community (Ogun State, Nigeria) (Solana et al.,2020), in Fiche (Oromia region, Ethiopia)(Sebsibe et al., 2021) and, in Kobo town (Northern, Ethiopia) (Sitotaw and Nigus, 2021).

Compared to the source and the reservoir, drinking water from taps and water containers was found to be very polluted with coliforms. This result is consistent with earlier reports from Kobo town in northern Ethiopia (Sitotaw and Nigus, 2021) and Boloso Sore woreda in southern Ethiopia (Gizachew et al., 2020); however, the current study is in opposition to the report from Shambu town (western Ethiopia), where water samples were shown to have lower TC counts compared to the sources and the reservoir. (Garoma et al., 2018). The disparity may be the result of inadequate water management and unsanitary conditions in sources and reservoirs.

One of the physicochemical criteria used to assess the quality of drinking water is temperature. The findings showed that the water samples' mean temperatures ranged from 20.53 to 25.5o C. In comparison to reservoirs, tap water, and end consumers, water sources were found to have significantly lower average temperatures (p 0.05). However, at a p 0.05 significant level, there was no change in the mean temperature between the sampled sites at the reservoir, tap water, and point of use. The mean temperature was reported to be 21.3 C and 23.8 C, respectively, in earlier studies conducted in Damot Sore Woreda (Bekele et al., 2018) and Nekemte (Duressa et al., 2019). Contrarily, in the current study, greater mean temperatures were found in the Afar region's Dubti, Amibara, and Awash-Fentale Woredas, ranging from 32 to 330 degrees Celsius and 40 to 530 degrees Celsius, respectively, from river and groundwater sources(Abadi, 2013).The discrepancy between the research region at hand and those in Afar may be the result of the ambient temperature differences. High temperatures and rainfall are characteristics of tropical climates, and these elements may have contributed to the high temperatures of water samples from various cities in Ethiopia that were above the WHO threshold of 15 oC (WHO, 2017).

The obtained mean pH values ranged from 6.689 to 7.014 and were generally within the 6.5-8.5 suggested standard limits. (ESA, 2013, WHO, 2017). At the p 0.05 significant level, there were no changes between the source, storage, and point of sampling sites' mean pH values. The results of the current study are comparable to the average pH records found in Damot Sore Woreda (Bekele et al., 2018) and Nekemte, Oromia, which range from 6.73 to 7.03 and 7.04 to 7.22, respectively (Duressa et al.,2019). The pH values in the current study are lower than those found in earlier investigations carried out in Adama (pH 7.8), Asmera (pH 7.8), and Ogun State, Nigeria (pH 6.72–8.48) (Solana et al., 2020). The geological characteristics of the water sources could be the cause of the variance. The correlation matrix revealed a poor link between pH and EC (r = -0.542/1.000, p 0.01) and no other physicochemical parameters had significant correlations at P 0.05 or 0.01.

In the present study, the highest EC (658.41µS/cm) was recorded from end users (Household Containers) whereas the lowest conductivity was recorded from the sample obtained from Reservoir (619µS/cm) and Tap water (622.25µS/cm). Nevertheless, the differences in the mean EC of the source, reservoirs, tap water, and households' container were not significant at $p \le 0.05$ significant level. The finding of the present study is comparable to the average EC record ranging between 566.33 µS/cm to 627.33µS/cm in Robe town, Oromia(Shigut et al., 2017). EC levels in drinking water of the present study area were higher than the reports of (Bekele et al., 2018, Duressa et al., 2019, Solana et al., 2020). These differences might be due to geological factors, agricultural activity, and the soil types of the study area. Electrical conductivity was positively correlated with turbidity (r = 0.422/1.00, $p < 0.05$), TDS (r=0.99/1.00 $p < 0.01$), Total Hardness (r=0.688/1.00 $p < 0.01$) and Magnesium (r=0.663/1.00 $p < 0.01$).

The highest turbidity was recorded in the source and the lowest turbidity was recorded in the end users. The average turbidity values of water sources were found to be significantly higher ($p < 0.05$) than those of reservoirs, tap water, and end users. However, the differences in the mean turbidity of the reservoir, tap water and point of sampled sites were not significant at $p < 0.05$ significant level. Turbidity values of source water and reservoirs did not comply with both Ethiopian standards and WHO which is 7 and 5, respectively (ESA, 2013, WHO, 2017). This slight turbidity indicates that there may be the presence of inorganic particulate matter and non-soluble metal oxides. Therefore, some primary treatment like coagulation and flocculation is needed to be carried out on water source before any disinfection treatment can be done, else, as excessive turbidity can protect pathogenic microorganisms from the effects of disinfectants (Hunter et al., 2009). Turbidity was positively correlated with TDS (r=0.42/1.00, $p < 0.01$) and Total Hardness (r=0.484/1.00, $P < 0.05$).

Total dissolved solids show the salinity behavior of groundwater. Total dissolved solids (TDS) indicate the amount of chemical substances dissolved in the water, which at increased levels in excess of 1500 mg/l (Maximum Permissible Level) decreases palatability and may produce a bad taste (WHO, 2011). In the present study, TDS values varied from 371.4 mg/L to 395.1 mg/L in end users and reservoirs, respectively. All samples analyzed were below the limit (1000 mg/L) given by (ESA, 2013, WHO, 2011). The values recorded in this study were comparably with the values (355mg/l - 414 mg/l) reported by (Shigut et al., 2017). TDS correlated positively with Total hardness (r=0.668/1.00, $P < 0.01$), magnesium (r=0.663/1.00, P <0.01).

Nitrate concentrations were 1.033 mg/l, 1.693 mg/l, 1.724 mg/l, and 2.12 mg/l in the water samples from the source, reservoir, tap water, and end consumers, respectively. Nitrate concentrations above the WHO(2017) and ESA(2013) standards of 50mg/L may result in blue baby syndrome or cyanosis disease in newborns less than three months (WHO, 2006). The results of the current investigation showed that the nitrate content is significantly lower than the NORM, and the researchers concluded that there is no nitrate problem in the study region based on these standards. Nitrate levels in end users were much greater than those in the source. However, there were no differences in nitrate concentrations across end consumers, tap water, and reservoir. The finding of the present study is less than the maximum values of 95.8 mg/L from the source waters of Jimma zone(Yasin et al., 2015), 8.4 mg/L from the source of Robe town (Shigut et al.,2017) and 38 mg/L from the source of shambu town(Garoma et al., 2018). The correlation coefficient(r) between Nitrate and Iron was (r=0.535/1.00, P <0.01). It indicates that as increasing one parameter increases the other one with strong association and vice versa (Shigut et al., 2017, Kassegne and Leta, 2020).The significant positive correlation ($p < 0.01$) of the stated water quality parameters could reveal that these ions have the same sources.

The results also revealed that the average phosphates were 0.583mg/l, 0.845mg/l, 0.598mg/l, and 0.761mg/l for the source, reservoir, Tap water and And-users (household container) respectively. The phosphate recorded in this study was slightly higher than the one recorded (0.4 -0.44mg/l) in Damot Sore Woreda (Bekele et al., 2018). Generally, groundwater contains only a minimum phosphorus level because of the low solubility of native phosphate minerals and the ability of soils to retain phosphate (Devendra et al., 2014).

The result of the water samples analysis shows that the concentrations of residual free chlorine were 0.21mg/l, 0.26mg/l, 0.23 mg/l, and 0.198mg/l for the source, reservoir, Tap water and And-users (household container) respectively. The mean value was within the expected range in the source, reservoir, and tap water, while it was slightly lower than the expected value in households' containers. These values are lower than the results reported recorded at Akaki Kality, Addis Ababa (0.67 mg/l) and at the treatment outlet of Ziway (0.79 mg/l) town (Birhanu, 2007, Bedane, 2008). Nevertheless, the FRC values were by far better than 0.03 mg/L recorded from the main distribution tank of Bahir Dar town(Kassahun, 2008).All water samples were within the recommended limit of WHO (0.5 mg/l), which indicates the efficiency of disinfection in the distribution system.

In the present study, the highest iron content was recorded in the household containers (0.056mg/l) and the lowest was recorded in the source (0.005mg/l). Based on the concentration of iron, all sources of the town are in an acceptable limits. Because WHO(2017) recommended that the maximum permissible level of iron in drinking water should be up to 0.3 mg/L. The shortage of iron causes disease called "anemia'' and prolonged consumption of drinking water with high concentration of iron may lead to liver disease called as haermosiderosis.

The mean total hardness as CaCO3 for the source reservoir, tap water, and household container were 67.3mg/l, 46.0mg/l, 55.45mg/l and 53.66mg/l respectively. Some reported studies have found very low mean values for the water hardness parameter: Damot sore Woreda, with a range of 39.36-49.63 mg/l (Bekele et al., 2018), in Robe Town with 32.44mg/l - 66.61mg/l (Shigut et al.,2017) and 34.2 mg/l in Calalbar municipality (Nigeria) (Agbo et al., 2019). Some of these reported values are compatible with the present study. It has been claimed that hardness is not considered of health concern at levels found in drinking water (WHO, 2011). Generally, increased water hardness is attributed to increased amounts of dissolved chlorides or sulphates of calcium and magnesium, although positively charged divalent ions, such as Fe, Sr, and Mn can also contribute to water hardness(Meena et al., 2012).

Magnesium is the 8th most abundant element in the earth crust and a natural constituent of water. It is essential for proper functioning of living organisms and found in minerals like dolomite, magnetite, etc. Human body contains about 25 g of magnesium (60 % in bone and 40 % in muscle and tissues)(Meride and Ayenew, 2016). The results of laboratory analysis revealed that the mean values of Magnesium for the source, reservoir, Tap water, and household container were 1.79mg/l, 1.533mg/l, 1.847mg/l and 1.903mg/l respectively. The values in this study were higher than those reported by Rahmanian et al. (2015) in drinking water samples of Perak state, Malaysia(Rahmanian et al., 2015). According to WHO (2017) standards, the permissible range of magnesium in water should be 30 mg/l. The finding of the present study was in agreement with the WHO (2017) and ESA (2013) standard value of potable water which is 30mg/L and 50 mg/l, respectively. There was no significant difference in mean values of magnesium among the various sampling sites at $p<0.05$ significant levels.

Fluoride concentrations of 0.7–1.2 mg/l in drinking water will protect against dental cavities. Nevertheless, excessive levels (more than 1.5 mg/l) may cause discoloration or mottling of the teeth. This occurs only in developing teeth before they push through. Higher fluoride levels also may cause skeletal damage and bone disease. The fluoride contents of the water samples in the current study were in the range 1.25 mg/l (Dore Bafano Reservoir) to 4.5 mg/l (Gamato borehole) (Annex 1). Based on the DRINKING water quality standards, the fluoride content of water samples in Dore Bafano reservoir and Umbulo tap were within the permissible limits. Regarding the Ethiopian drinking water limit of fluoride, it is below the value (3 mg/L) in Dore bafano reservoir, Umbulo tap, Umbulo reservoir and Rukesa tap.

Conclusions

The water sample collected was tested for bacteriological (FC and TC) and physicochemical parameters such as temperature (T), pH, EC, TDS, NO_3^-, NH_3, PO_4^{3-}, Free chloride residual, Fe, TH, Mg^{+2}, NO_2^-, F^-, Mn, Pb, Zn, Co, Cu and Ni were measured. Physico-chemical parameters of water from the Hawassa Zuria Woreda were to be within the safe drinking water guidelines set by WHO. However, the physicochemical parameters that surpassed these safe guidelines in different sampling sites were temperature, electric conductivity, ammonia, phosphate, fluoride, lead, and nickel. The concentration of F^- was found higher than the permissible levels of F^- for safe drinking water set by the WHO. Total coliforms were detected in forty-three percent of the water samples although about one-quarter of the water samples were positive for fecal coliforms (FC) and hence did not obey to the WHO guidelines and Ethiopian standards. The WQI values of the analyzed water samples indicate that 73.9% of all analyzed samples were excellent and 26.1% were good.

Some heavy metals (Pb and Ni) in some water samples were higher than the International standard maximum allowable limits that are the sample site (Betemengist Reservoir 2, Galo Tap 1, and Umbulo Reservoir) that was implicated by nickel concentration above the recommended limit. The high level of lead at the site (Gameto borehole, Boqo borehole, and Umbulo tap), which may be due to domestic sewage (plumbing), piping used for the water distribution system and extensive agriculture practices in the study area. The mean HPI and HEI were 75.72 and 1.47, respectively. Twenty percent of the water samples had HPI values greater than the critical value of 100. The distribution of average metal concentrations in the drinking water was found in the order of Zn>Ni>Co>Cu>Mn>Pb.

Based on the above conclusion, the following are recommended:

The groundwater of Hawassa Zuria Woreda is, although fit for domestic and drinking purpose, need treatments to minimize the contamination, especially the Electric conductivity, Ammonia, Phosphate, Fluoride, Lead, and Nickel.

This study strongly recommends the banning of drinking water from contaminated sites with heavy metals and the establishment of safe water for domestic use.

The authorized body should be given special attention to remove the lead and nickel. The level of Ca, K, Na and Cd must be analyzed for next.

Support further studies to be conducted on other physical, chemical, and biological parameters of significant health concern.

The local regulatory authorities should urgently move in to assess the quality of all existing water points in order to evaluate the quality of water for drinking purposes with respect to physicochemical parameters, heavy metal concentration

It is recommended to check the quality of the water sources regularly in the study area.

It is recommended that further research should be a study of other trace heavy metals like mercury, arsenic, and cadmium to confirm the study reliability.

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