ANALYTICAL CHEMISTRY | RESEARCH ARTICLE

Determination of physicochemical parameters of “Hora” natural mineral water and soil in Senkele Kebele, Oromia Region, Ethiopia

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Abstract: In this study, the mean levels of anion and metals in “Hora” natural mineral water and soil were determined. Accordingly, the levels of N–NH₃, Cl⁻, N–NO₃⁻, SO₄²⁻, Mg, and Ca in water were not exceeding the World Health Organization (WHO) drinking water guideline values for humans and the levels of N–NO₃⁻, SO₄²⁻, and Ca were also far below the Canadian Ministers of Health (CMH) guideline values for livestock. The levels of Al, Mn, Zn, Cu, Ni, Pb, and Mo were above the WHO guideline values, while majority of the trace metals were not exceeding the maximum permissible value for livestock except for Ni and Co. Among the trace metals found in the soil, Mn and Pb were found to be higher compared to the recommended value (40 mg/kg) by the Ethiopian guideline. The drinking water quality index (DWQI) was calculated to be 67.6 based on 21 important quality parameters.

Subjects: Environment & Resources; Environment & Health; Research Methods in Environmental Studies; Environmental Change & Pollution; Chemistry

Keywords: “Hora” natural mineral water; physicochemical; level of metals and anions

ABOUT THE AUTHORS

Tibebu Alemu, Eyobel Mulugeta, and Miresa Tadese have spent together as a member of a research group for couple of years mainly focusing on physicochemical characterization of drinking water using different analytical techniques. Our research group has equipped with the state-of-the-art analytical instruments which are capable of determining trace level of water pollutants. Besides, method development and statistical data analysis are also main components of our research. In addition, the authors have the experience with pollution prevention measures and environmental protection agency compliance standards at national and international levels. In wider context, the research group has been working in treatment of drinking water using locally available materials, specifically using adsorption method in continuous mode.

PUBLIC INTEREST STATEMENT

Natural mineral waters may be distinguished from ordinary drinking water by their purity at source and their constant level of minerals. In addition, natural mineral water has beneficial medical and therapeutic effects. However, it is more prone to contamination mainly from anthropogenic activities such as agriculture and urbanization. Therefore, there is a need to examine its quality periodically. This study aims to investigate physicochemical characteristics of “Hora” natural mineral water, which is located in Western Ethiopia. This study reports that Hora mineral water was contaminated with salts and trace metals which could affect both human and animal health. These might be attributed to the utilization of old galvanized plumbing systems and natural sources such as the geological formations through which the ground water flows. Therefore, measures should be taken to improve the quality of drinking water through either replacement of the old pipes or treatment of the water beforehand.
1. Introduction

1.1. Background of the study

“Hora” is one of the natural mineral water found in West Shoa Zone, Ambo Woreda. It serves as a main water supply for the people living in Senkele, a small district just 3 km to Southwest of Ambo town (1). According to elder people’s in Senkele district, the “Hora” water was used by livestock for drinking purpose long time ago. Senkele district is facing severe shortage of drinking water; as a result, people in this area use “Hora” for drinking, sanitation, and irrigation. It is believed that, “Hora” water is still used as natural medicine to cure people and livestock with health problems, so that it needs to be given special attention. It is observed that livestock always prefer to drink “Hora” water. It is also noted that white precipitate is clearly seen when people wash their body with “Hora” water.

Mineral water has been used in human nutrition, especially in the different stages of life, during physical activity and in the presence of some morbid conditions. The use of drinking mineral water as therapeutic and preventive remedies for many diseases affecting the respiratory tract, skin, liver, intestine, gynecological apparatus and osteoarticular system has been demonstrated (2). Most authors (3, 4) have suggested that thermal water is valid tool in the treatment of illnesses, such as functional dyspepsia, irritable bowel syndrome and functional disorders of the biliary tract, because carbonated water stimulates the secretion and motility of the digestive tract. Furthermore, salt-rich mineral water enhances the conversion of cholesterol into bile acids and their subsequent secretion (5).

The composition, temperature, and other essential characteristics of mineral water must remain stable over time. During the fossilization of this type of water, the concentration of most components increases with respect to the original composition. The chemistry highly depends on the availability of mineralizing agents, such as temperature, CO₂ concentration, redox conditions and the type of adsorption complex. Mineral water contains different types of dissolved substances, namely minerals and other biological compounds. Special mineral composition in any mineral water might have properties favorable to health, which should be assessed by clinical and pharmacological analyses. These health benefits were studied, particularly in Eastern European spas (6, 7).

Spring mineral water has antioxidant, hypocholesterolaemic activity and may affect calcium metabolism (8). For example, sulfurous mineral water was found to have antioxidant properties and a positive effect on the oxidative defense mechanism on both rabbits and rats, respectively. The oral intake of water containing calcium increases serum calcium and inhibits intact parathyroid hormone secretion (9). However, results vary depending on the type of water mineralization (10). Epidemiological studies carried out on mineral water had found the relations between the mineral content of drinking water and the cardiovascular disease mortality rate in various countries (11). Some studies demonstrated a positive geographical correlation between stroke-associated mortality and river water acidity (12, 13).

Drinking water quality guidelines and standards are designed to enable the provision of clean and safe water for human consumption, thereby protecting human health. These are usually based on scientifically assessed acceptable levels of toxicity to either humans or aquatic organisms (14).

The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life (15). The increased use of metal-based fertilizer in agricultural revolution could result in continued rise in concentration of metal pollutions in fresh water reservoir due to the water run-off. Metals in water occur as complex and mixture of soluble and insoluble form, such as ionic species, inorganic and organic complexes associated with colloids and suspended particulate matter. Metals are probably the most harmful pollutants, if their concentration is higher than the permissible limits. These metals have accumulative effect at low level in drinking water. Food chain transfer also increases toxicological risk in humans (16).
Consequently, the toxicity and sedimentation potential of metals change depending on their speciation. The environmental pollutants tend to accumulate in organisms, and become persistent because of their chemical stability or poor biodegradability (17). Soil is one of the repositories for anthropogenic wastes. When agricultural soils are polluted, these metals are taken up by plants and consequently accumulate in their tissues. Animals that graze on such contaminated plants and drink polluted water would also accumulate such metals in their tissues and milk if lactating (18).

The cattle around Senkele district are not only drink “Hora” natural mineral water, but also eat the soil around the water. The people living in the area always ride their cattle to the water, especially at the beginning of autumn because the cattle infected by some diseases use the water as medicine. Thus, these observations have initiated us to explore the physicochemical properties of the natural mineral water and the soil surrounding it. The general aim of the present study was to investigate physicochemical characteristics, concentration of some selected anions and metals of “Hora” natural mineral water and the soil surrounding it. Specific objectives sought were: (i) to determine some selected physical and chemical parameters of the “Hora” natural mineral water; (ii) to determine some selected physicochemical parameters in soil surrounding “Hora”; and (iii) to compare the result of this study with that of national and international drinking water standard values for human and livestock.

2. Methodology

2.1. Description of the study area
Ambo is one of the 180 Woreda’s in West Shoa Zone, Oromia Regional state of Ethiopia. Ambo is located 112 km west of the Addis Ababa, and is located at approximately between 8° 47’30” N–9° 21’30” N latitude and between 37° 32′30″ E–38° 15′15″ E longitude with an elevation of 2101 m above sea level. The town has four Kebeles with a population of approximately 65,000. Ambo is popular for its immense natural gifts including excellent climate which provides comfortable living and working environment. Despite its proximity to the equator, Ambo enjoys a mild, Afro-Alpine temperate and warm temperate climate. The lowest and highest annual average temperature are 13 and 27°C, respectively. April and May are the driest months. The main rainy season occurs between mid-June and mid-September, which is responsible for 70% of the annual average rainfall of 1,100 mm. It is characterized by intense rainfall of short duration. During the dry season, the days are pleasantly warm and the nights are cool. During the rainy season both days and nights are cool (1). Figure 1 shows the map of the study area in West Shoa Zone.

2.2. Analytical procedures

2.2.1. Sample collection
Composite sampling method was used to collect both water and soil. Both samples were taken three times (first-third week of April, 2016) and the mean values were reported. This is because, April is characterized by relatively high temperature weather and thus, water shortages will be expected for the upcoming months until rainy season comes. Therefore, more people and animals are expected to drink water from the site. About 1 L of water sample was randomly collected by polyethylene bottles from surface, middle, and bottom of well with one meter depth (19).

Soil samples were collected from the site around of the well and center (20). At each sampling point the samples were collected at surface level (10–100 cm in depth) with an area of one square meter. The soil samples then bulked together to form a composite sample before being placed in glass container and kept at temperature ≤4°C. Finally, the representative samples were preserved in an ice bag and immediately transported to the Ambo University Chemistry Laboratory.

2.2.2. Sample preparation
Water samples were brought to the laboratory for analysis after being acidified with nitric acid (for metal analysis) and chromic acid (for other physicochemical analysis) to a pH below 2.0 (21). For
determination of phosphorous, the samples were prepared by sulfuric acid-nitric acid digestion method as described in APHA 4500 P (22). For determination of sodium and potassium, samples and standard solutions were digested for 30 min on hot plate in hood and the concentrated solutions were collected and transferred through filtration to 100 mL volumetric flask containing distilled water. Prior to analysis of metals in the water sample, 5 mL of 71% HNO₃ was used to digest the samples for 30 min on hot plate in fume hood.

Soil samples were air-dried at ambient temperature and sieved to remove stones and plant debris, and grinded with a mortar and pestle. Digestion of soil samples was optimized and tested (23) by varying digestion time, reagent volume, volume ratio of reagents, and digestion temperature. Soil samples were digested using the optimized condition and left to stand until the vigorous reaction ceased. The digest was then filtered into volumetric flask.

2.2.3. Analysis of samples

2.2.3.1. Analysis of water samples. For unstable parameters such as temperature, electrical conductivity (EC), total dissolved solid (TDS), and pH were measured at the sampling site. Temperature, EC, and TDS were measured by conductivity meter (Postfach 24 80, Germany). pH values were measured using a pH meter (ELMETRON, CPI-501, Poland) which was calibrated by buffer solution of pH 4, 7, and 9.2. The analytical methods were adopted from American Public Health Association (22). The dissolved oxygen in water sample was analyzed by Winkler method as described in APHA method 4500-O. The total hardness and calcium content of water sample was determined by EDTA titrimetric method 2340 C and 3500-Ca B, respectively. The magnesium content was then calculated from total hardness and calcium. The total acidity and total alkalinity were determined by titration method described by APHA method 2310 and 2320, respectively. The chloride content in water sample was analyzed by argentometric method 4500-Cl⁻ B. Phosphorus determination was carried out by ascorbic acid method 4500-P E using UV–vis spectrophotometer (ELICO, Double beam SL 164, India). N–NH₃ and N–NO₃⁻ were determined by UV–vis spectrophotometer using phenate method 4500-NH₃ F and
screening method 4500-NO₃⁻ B, respectively. Sulfate ion (SO₄²⁻) was measured using turbidimetric method 4500-SO₄²⁻ E and light absorbance of BaSO₄ suspension was measured by UV–vis spectrophotometer. Sodium and potassium were determined by flame emission photometric method 3500-Na B and 3500-K B, respectively. The instrument used was ELICO (CL 378, India). The concentration of metals was determined by APHA method 3120 A and 3125 A using ICPOES and ICPMS, respectively.

2.2.3.2. Analysis of soil samples. Seven replicates, each containing 10 g of soil sample, were soaked in 25 mL of distilled water and shaken for 30 min using GEMMY orbit shaker (VRN-480, Taiwan). Then, pH and EC were measured according to ISRIC method (24). The moisture content of the samples was determined by oven drying method (24) using an oven (101-0, Mingda Technology Co. LTD, China). The carbon content was determined by Walkley–Black method, which involves wet combustion of organic matter with a mixture of K₂Cr₂O₇ and H₂SO₄ at about 125°C (24). The total nitrogen content was determined by micro-Kjeldahl method (24). Total phosphorous content in the soil was determined by nitric-perchloric acid wet digestion method described by (25). The digest was allowed to cool, filtered and the residue was washed to bring the volume of solution till 250 mL mark. Then, the total phosphorous was determined by UV–vis spectrophotometer at 882 nm after addition of coloring reagents. A 0.5 g of dried, powdered, and sieved soil sample was measured and added to digestion tube. To all of the above digestion tubes, 5 mL of concentrated HNO₃ was added to acidify it. Then to all samples 3 mL of HClO₄ and 2 mL of H₂O₂ were successively added as it was optimized earlier. The mixture was digested in Kdeljal digester for 3 h at 300°C and was cooled followed by filtration using Whatman No. 50 filter paper. The concentration of Na and K was determined by flame photometer (ELICO, CL 378). Similarly, for analysis of metals, the optimized acid wet digestion method was used to determine Fe, Co, Mn, Zn, Cu, Ni, Cr, Pb, and Mo by ICPOES (Agilent 720 ICP-OES, Australia).

2.2.4. Water quality index

Drinking water quality index (DWQI) is a mathematical instrument used to transform large quantities of water quality data into a single number which represents the overall drinking water quality status. In this study, 21 parameters were selected (temperature, pH, electrical conductivity, dissolved oxygen, Na, Cl⁻, SO₄²⁻, total alkalinity, total hardness, Ca, Mg, Fe, NO₃⁻, total phosphorous, Mn, Zn, Cd, Cr, Pb, Cu, and Ni). Regarding to sub-index development, each parameter had been assigned a rating value between 0 and 100 based on its desirable and acceptable limits of guideline values prescribed by WHO (26). Then, the DWQI was calculated using weighted additive (arithmetic) drinking water quality index (DWQI(A)) (27):

$$DWQI_{(A)} = \sum_{i=1}^{n} SI_i \times W_i$$

where, SIi is the sub-index value of ith parameter, W is the weight factor of ith parameter, and n is the total number of parameters (n = 21).

This index reduces huge amounts of data to a single number, thus ranking water into one of five categories: very bad (0–25), bad (25–50), medium (50–70), good (70–90), and excellent (90–100).

3. Results and discussion

3.1. Physicochemical characteristics of water

3.1.1. Major physical and chemical parameters

The temperature readings were ranging from 27.4 to 28.4°C. The esthetic objective for temperature of drinking water should be less than or equal to 15°C as it is adopted from the guidelines for Canadian drinking water (28). Temperature above 15°C enhances the growth of nuisance organisms and may increase problems related to taste, odor, color, and corrosion. Cattle typically prefer drinking water at temperatures between 4.4 and 18.3°C. When the temperature is more than 27°C, water and feed intake rates often decrease, affecting animal productivity (26).
The electrical conductivity was found to be 1,820 μS/cm, which is above the Ethiopian guideline (1,000 μS/cm) and WHO (1,500 μS/cm) (26, 29). This may be associated with the presence of dissolved salts of sodium, bicarbonate, sulfate, calcium, magnesium, and silica. Agricultural run-off can also raise conductivity values in water bodies. Soluble salt in drinking water have different effect on livestock for example, if the value is less than 1,000 mg/L, it is safe to drink and pose no health problems. If it is in between 1,000 and 2,999 mg/L, typically is safe to drink, may cause mild diarrhea; while 3,000–4,999 mg/L, cattle may initially refuse, may cause diarrhea and optimal performance not achieved due to lower water intake rates (30).

The total dissolved solids in the sampled water ranged from 479.8 to 577.4 mg/L. The palatability of water with a total dissolved solids (TDS) level of less than about 600 mg/L is generally considered to be good; drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1,000 mg/L (31). To date no health-based guideline for TDS has been proposed in Ethiopia, however, 1,000 mg/L for humans and 10,000 mg/L for livestock are the recommended values. The TDS value was also found to be in the range of water quality guideline for livestock. In this study, there was a strong correlation ($r = 1.0$) between EC and TDS.

The pH readings were between 6.49 and 6.53. They were within the national and WHO water quality guidelines of permissible range of 6.5–8.5 for natural water bodies (26, 29). The pH values were also within the range of water quality guideline for livestock (32).

The higher value of dissolved oxygen indicates good aquatic life. The amount of dissolved oxygen of “Hora” natural mineral water was between 0.92 and 1.14 mg/L. The lowest dissolved oxygen recorded might be due to the high temperature (33). No health-based guideline value is recommended by Ethiopian, but it is below permissible limits according to WHO standard. No standard value was given by national and international for livestock.

Total hardness levels from the various sampling sites ranged from 370.4 to 377.1 mg/L, which were much lower than the WHO recommended levels for drinking water is 400 mg/L. This hardness might be as the result of limestone and magnesium terrain crossed by water. Hardness of water does not pose a health risk but can cause esthetic problems. These problems include the formation of scale or precipitation on piping and fixtures causing water pressures and interior diameters of piping to decrease, and causes alkali taste in water. According to hardness (mg/L) guidelines for livestock, different classification of water could be observed. For example, if the hardness is 0–60, the water is soft, 61–120 it is moderately hard, 121–180 it is hard, 181–350 is very hard, while >350 is brackish (26).

Calcium is most abundant ions in fresh water and is important in shell construction, bone building and plant precipitation of lime. The analysis of calcium revealed that the values were between 132.1 and 136.7 mg/L. The permissible level set by Ethiopian is 200 mg/L. Calcium is an important element for good health and levels between 20 and 30 mg/L are desirable in drinking water. Very high levels of calcium, however, will produce scale and clog up water pipes. Calcium is one of the major elements responsible for water hardness. Water containing less than 60 mg/L of Ca is considered as soft water (34).

Magnesium is often associated with calcium in all kinds of water, but its concentration remains generally lower than the calcium. Magnesium is essential for chlorophyll growth and acts as a limiting factor for the growth of phytoplankton (29). The amount of magnesium recorded in the water sample was between 7.5 and 10.8 mg/L, which is below the WHO and Ethiopian guideline values. The $\text{Mg}^{2+}/\text{Ca}^{2+}$ ratio for “Hora” mineral water was 0.068. The molar ratios lie mostly in the range 0.20–1.84, indicating weathering of pure dolomites; however, the lowest value indicates for relatively impure lower triassic dolomites.
Total alkalinity observed in the present study was ranged from 968.3 to 1,022.9 mg/L. The alkalinity of surface water is primarily a function of bicarbonate, carbonate, and hydroxide content; it also includes the contributions from borates, phosphates, silicates, and other bases. The highest alkalinity recorded during the study period might be due to high nutrients in water. There is no health based guideline value for alkalinity but it does contribute to the amount of total dissolved solids (TDS) which has an esthetic guideline value of 400 mg/L. Levels between 30 and 400 mg/L are suitable for human drinking water, while no standard value was set for livestock both at national as well as international level.

The acidity of water will affect its corrosiveness and also the speciation of some of its other constituents. The total acidity measured for “Hora” water was ranged from 130.4 to 141.1 mg/L. However, there is no health based guideline for drinking water regarding humans and cattle.

The amount of chloride found in the test samples ranged from 15.77 to 16.83 mg/L, which were far below the WHO value of 250 mg/L and hence, does not pose any immediate health risk to consumers. In portable water, the salty taste is produced by the chloride concentrations and its variable and dependence on the chemical composition. No guideline stated showing chloride content for cattle drinking water.

The result for total phosphorous was below detection limit, which is unexpectedly low. This is because the sample was taken from source where there is no contamination from agricultural field such as fertilizers.

The amount of nitrate (N–NO\textsubscript{3}\textsuperscript{−}) recorded in the sample of “Hora” mineral water ranged from 1.31 to 2.23 mg/L. The WHO guideline value for nitrate is 50 mg/L as nitrate ion (11 mg/L as nitrate-nitrogen) in drinking water and 100 mg/L CMH guideline for livestock. Hence, the level of nitrate is by far below the permissible level. Follett et al. (35), stated that low levels of nitrogen (in the form of nitrate) are normal in groundwater and surface water. However, elevated nitrate caused by human activity is a pollutant in the water.

The level of ammonia (N–NH\textsubscript{3}) in the water samples were in the range of 0.73–1.17 mg/L, which is above the permissible limits for drinking water. Natural levels in groundwater and surface water are usually below 0.2 mg/L. Anaerobic groundwater may contain up to 3 mg/L. Intensive rearing of farm animals can give rise to much higher levels in surface water. Thus, ammonia in the water sample might be due to possible bacterial, sewage and animal waste pollution. Ammonia in drinking water is not of immediate health relevance, and therefore no health-based guideline value is proposed for livestock. Another reason is that at a higher alkalinity, ammonia will be the predominate form.

Sulfate contents in the water samples were in the range of 5.59–13.07 mg/L, which is far below the WHO recommended value of 500 and 1,000 mg/L for livestock as CMH guideline. No health-based guideline is proposed for sulfate. However, because of the gastrointestinal effects resulting from ingestion of drinking water containing high sulfate levels, it is recommended that health authorities be notified of sources of drinking water that contain excess sulfate concentrations.

The concentration of sodium in test sample was ranged from 580.2 to 635.8 mg/L. Though, there is no health-related guideline value for sodium, for esthetic reasons (taste) sodium should not exceed 200 mg/L. The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution (26).

The potassium concentration in test sample was 160.1–165.9 mg/L. It is not considered necessary to establish a health-based guideline value for potassium in drinking water. Although potassium may cause some health effects in susceptible individuals, potassium intake from drinking water is well below the level at which adverse health effects may occur (36) (Table 1).
3.1.2. Trace metals

The levels of trace metals determined in “Hora” mineral water are presented in Table 2. Most analyzed water samples showed measurable concentrations of the trace metals except Fe and Cd. The level of Al, Mn, Zn, Cu, Ni, Pb, and Mo was above the guideline value set by WHO, whereas the remaining trace metals were all below the guideline value. The data used for further discussion were the results exhibited high concentration above the recommended values.

Aluminum concentration was about 0.84 mg/L. There is no health-related guideline value for aluminum in drinking water. It is recommended that the concentration should not exceed 0.2 mg/L. However, the observed concentration level of aluminum was excess of acceptable limits given by WHO guidelines.

Manganese occurs in over 100 common salts and mineral complexes that are widely distributed in rocks and soils. Manganese is generally present in natural surface water at concentrations below 0.04 mg/L. However, the level of Mn in “Hora” mineral water was about 0.92 mg/L, which is above the recommended value. It is more prevalent in groundwater supplies owing to the reducing conditions that exist underground. Manganese is an essential element in humans and animals. It is regarded as one of the least toxic elements; toxicity in humans is usually the result of chronic inhalation of high concentrations of manganese in dust from industrial sources. At levels exceeding 0.15 mg/L, manganese stains plumbing fixtures and laundry and causes undesirable tastes in beverages. It may lead to the accumulation of microbial growths in the distribution system that could give rise to taste, odor, and turbidity problems in the distributed water (26).

The main industrial uses of zinc are galvanization and preparation of alloys. The main source of zinc in natural water including drinking water may be galvanized pipes. Zinc concentration was ranged from 0.1 to 0.108 mg/L, and the average value was 0.104, which is slightly above the WHO recommended value. Although Zn is crucial for human health, as it functions as a catalyst for enzymatic activity, excessive concentrations of this metal can cause harmful side effects such as an acceleration of the conditions associated with anemia (37).
Copper contaminating drinking water as a corrosion by-product occurs as the result of the corrosion of copper pipes that remain in contact with water for a prolonged period. The concentration of copper was found to be 1.11 mg/L. Copper is an essential nutrient, but at high doses it has been shown to cause stomach and intestinal distress, liver and kidney damage and anemia.

Concentration of nickel in drinking water is normally less than 0.02 mg/L, although nickel released from taps and fittings may contribute up to 1 mg/L. The mean level of Ni in this study was 1.08 mg/L. In special cases of release from natural or industrial nickel deposits in the ground, concentrations in drinking water may be higher. Water that has come into contact with nickel or chromium-plated taps, the nickel contribution from water may be significant.

The concentration of lead in the water sample was 0.50 mg/L, which is by far exists at higher concentration compared with the guideline value of 0.01 mg/L. Lead concentrations increase with increasing standing time of water in lead pipe. Lead can corrode more rapidly when it is coupled to copper. Lead is a cumulative general poison, with foetuses, infants, young children, and pregnant women being most susceptible to adverse health effects. Lead can severely affect the central nervous system.

Molybdenum is found naturally in soil. Concentrations in drinking water are usually less than 0.01 mg/L, however, concentrations below 0.02 mg/L have been recommended by WHO for drinking water. On the other hand, the concentration of Mo in the test sample was around 0.07 which is higher than the recommended value.

Concerning livestock, the level of trace metals determined in “Hora” natural mineral water was below the drinking water guideline for livestock except for Ni and Co.

Therefore, the most probable cause for high level of the aforementioned trace metals may be the use of galvanized pipes in the water point. Based on specifications provided by the American Society for Testing and Materials (ASTM) designations B88-09 and A53/A53M-12, the galvanized pipe contains Fe, C, Mn, P, S, Cu, Ni, Cr, Mo, V, and the Zn-coating used to galvanize the pipe. Copper pipe also contains Cu and trace amounts of P (38, 39). Thus, concentrations of these elements might increase in drinking water after prolonged contact with the pipes. Another reason could be attributed to the geological formations through which the ground water flows (40) and substances dissolving from either natural source.

Studying the trends in trace metal concentrations with distance away from the water point will definitely confirm our hypothesis in the future (Table 2).

| Table 2. Mean levels of trace metals in “Hora” natural mineral water |
|----------------------|-----------------|-----------------|------------------------|
| **Heavy metal**      | **Concentration (mg/L)** | **Regulation, WHO (mg/L)** | **Livestock water quality, WHO guideline (mg/L)** |
| Fe                   | <DL             | 0.30            | –                      |
| Si                   | 16.39 ± 0.017   | –               | –                      |
| Sr                   | 0.5293 ± 0.004  | –               | –                      |
| Al                   | 0.8362 ± 0.002  | 0.20            | 5.0                    |
| Co                   | 1.092 ± 0.004   | –               | 1.0                    |
| Mn                   | 0.924 ± 0.004   | 0.60            | –                      |
| Zn                   | 0.104 ± 0.004   | 0.10            | 24                     |
| Cu                   | 1.114 ± 0.017   | 1.00            | 1.5                    |
| Ni                   | 1.082 ± 0.015   | 0.02            | 1.0                    |
| Cd                   | <DL             | 0.003           | 0.05                   |
| Cr                   | 0.031 ± 0.002   | 0.05            | 1.0                    |
| Pb                   | 0.502 ± 0.011   | 0.01            | 0.1                    |
| As                   | 0.0004 ± 0.003  | 0.01            | 0.2                    |
| Se                   | 0.0002 ± 0.0001 | 0.01            | 0.05                   |
| Mo                   | 0.067 ± 0.003   | 0.02            | –                      |
3.2. Physicochemical characteristics of soil

3.2.1. Major physical and chemical parameters
Electrical conductivity of the soil samples were found to lie between 1,435.4 and 1,594.6 μS/cm. A very strongly saline soil has an EC of more than 3,200 μS/cm. Crops vary in their tolerance to salinity and 400 μS/cm is considered as optimum for all crops (41).

The soil pH is an important parameter because it influences the chemical and physiological processes in the soil, and the availability of plant nutrients. The pH of the soil sample was ranged from 8.73 to 8.77, which is moderately alkaline. It has more proportions of sandy soil. Alkaline soil contains relatively high concentration of K, Mo, S, Ca, Mg, and P.

Soil organic carbon plays an important role as a source of plant nutrients and in maintaining the soil integrity. Organic matter also plays a major role in determining soil physical characteristics; soils with medium to high OM levels would generally be expected to have good structure, moisture retention and water infiltration. The total carbon content and organic matter were found to be 0.154 and 0.265, respectively. This indicates that, the level of %TC and %OM were very low in the soil sample collected around water source.

The total nitrogen (TN) content of the soil is characterized as both chemically stable humus and partially decomposed plant and animal residues of organic matter fractions. The test sample contained 0.479%N, which indicates that the total nitrogen content is high.

Soil moisture content was observed as 7.66% in test samples. Dry conditions can result in less movement of nutrients into the plant.

Sodium is only of secondary importance in the soil test as its uptake by plants is largely dependent on the plant species involved and the potassium status of the soil, rather than the actual level of sodium extractable from the soil. This element is mainly of interest for animal health and can generally be ignored for cropping and horticultural situations. Potassium is an essential nutrient and it has an important role in the growth of plants. Sodium and potassium values of soil samples, around “Hora” mineral water, were 9.45 and 10.2 cmol/kg, respectively. Both elements have shown elevated level over the optimum value (Table 3).

### Table 3. Physicochemical analysis of soil around “Hora” natural mineral water

| Parameters          | Unit     | Soil level    | Desirable limit |
|---------------------|----------|---------------|-----------------|
| Conductivity        | μS/cm    | 1515 ± 79.6   | –               |
| pH                  |         | 8.75 ± 0.02   | 5.5–8.5         |
| Organic carbon      | %        | 0.154 ± 0.024 | 2               |
| Total carbon        | %        | 0.265 ± 0.042 | –               |
| Nitrogen            | %        | 0.479 ± 0.020 | –               |
| Moisture content    | %        | 7.660 ± 0.061 | –               |
| Total phosphorous   | mg/kg    | <DL           | –               |
| Na                  | cmol/kg  | 9.449 ± 0.181 | 2.0             |
| K                   | cmol/kg  | 10.213 ± 1.039| 0.5             |

3.2.2. Trace metals
Among the trace metals measured in the soil, lead and manganese were found to be at higher concentration as compared to the recommended value (40 mg/kg) by Ethiopian guideline. This was also implicated in the level of Pb and Mn in “Hora” mineral water (Table 4).
3.3. Water quality index

The data of water quality index (WQI) based on 21 important parameters has indicated that the sampled water has DWQI of 67.6, which is categorized under medium quality water. Therefore, measures should be taken to improve the quality of drinking water through replacement of the old pipes with new one or treatment of the water beforehand.

4. Conclusions

The physicochemical study of “Hora” natural mineral water has shown that the level of TDS, pH, TH, Ca, Mg, total acidity, chloride, N–NO₃⁻, and SO₄²⁻ were under the acceptable limit of drinking water quality standards. Whereas, the level of temperature, electrical conductivity, dissolved oxygen, total alkalinity, N–NH₃, Na, and K were above the guideline values. This may have direct association with beneficial effects on human and animal health of the “Hora” mineral water, as it is supported by literatures. The high levels of trace metals (Al, Mn, Zn, Cu, Ni, Pb, and Mo) in the test water are attributed to substances dissolving from either galvanized plumbing systems, as it is observed from the water distribution system, or natural sources such as the geological formations through which the ground water flows. In contrast, the level of trace metals determined in “Hora” mineral water was below the drinking water guideline for livestock except for Ni and Ca. Among the trace metals analyzed in the soil, Mn and Pb were higher compared to the recommended value by the Ethiopian guideline and thus it is an evidence for the transfer of these metals into the water. The data of water quality index (WQI) based on 21 important parameters has indicated that the sampled water has DWQI of 67.6, which is categorized under medium quality water. Even though, the present study has made complete water quality assessment in which nobody has ever tried before, further studies in the area of microbiology or medicine should be conducted in the future. Meanwhile, measures should be taken to improve the quality of drinking water through either replacement of the old pipes or treatment of the water beforehand.

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Note

1. Natural mineral water having salty test and very attractive by cattle.

References

(1) Central Statistical Authority (CSA). Population and Housing Census of Ethiopia: Results for Oromia Region; Central Statistical Authority: Addis Ababa, 2012.
(2) Grossi, M.; Lucchetta, M.; Grossi, F.; Raffa, S. Possibilities of Thermal Medicine in Gastrointestinal Functional Disorders. La Clin. Ter. 2002, 153 (3), 195–199.
(3) Fioravanti, A.; Valenti, M.; Altobelli, E.; Di Orio, F.; Nappi, G.; Crisanti, A.; Cantarini, L.; Marcolongo, R. Clinical Efficacy and Cost-effectiveness Evidence of spa Therapy in Osteoarthritis. The Results of “Niaide” Italian Project. Panminerva Med. 2003, 45, 211–217.

Table 4. Trace metal content of soil around Hora mineral water

| Heavy metal | Soil (mg/kg) | Ethiopian guideline (mg/kg) |
|-------------|--------------|------------------------------|
| Fe          | <DL          | –                            |
| Co          | 218 ± 0.008  | –                            |
| Mn          | 367 ± 0.003  | 40                           |
| Zn          | 262 ± 0.015  | 500                          |
| Cu          | 225 ± 0.011  | 500                          |
| Ni          | 26.0 ± 0.003 | 30                           |
| Cr          | 34.8 ± 0.001 | 500                          |
| Pb          | 103 ± 0.003  | 40                           |
| Mo          | 3.40 ± 0.001 | 5                            |
(38) ASTM Standard B88. Standard Specification for Seamless Copper Water Tube; ASTM International: Washington, DC, 2009.
(39) ASTM Standard A53/A53M. Standard Specification for Pipe, Steel, Black and Hot-dipped, Zinc-coated, Welded and Seamless; ASTM International: Washington, DC, 2012.
(40) Fiket, Z.; Roje, V.; Mikac, N.; Kniewald, G. Determination of Arsenic and Other Trace Elements in Bottled Waters by High Resolution Inductively Coupled Plasma Mass Spectrometry. Croat. Chem. Acta 2007, 80, 91–100.
(41) Bosal. Guidelines for Interpretation of Soil Analyses; Suite K, Hollister, CA, 2008
(42) Canadian Ministry of Health. Guidelines for Canadian Drinking Water Quality. 6th ed.; Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial Committee on Environmental and Occupational Health: Canada, 1996.