

Research Article

Quality Assurance of Water Sources in Selected Areas of Southern Eritrea: Traditionally Used as Medication for Kidney Stones

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Abstract

The aim of this study is to access the chemistry behind the potential use of water as medication and assure the quality of water sources in certain areas of Southern Eritrea. The sources were boreholes and lifting device varied from solar to hand-pump. Quality of the water sources were examined by measuring the physicochemical parameters, bacteriological contaminants and heavy metal contents. The digital pH meter, conductivity meter, turbid meter, flame photometer, spectrophotometer, and ICP-AES instruments were employed to access the water quality. The physicochemical parameters measured were pH, temperature, turbidity, electrical conductivity (EC), total alkalinity (TA), total hardness (TH), Na⁺, K⁺, mg²⁺, Ca²⁺, Mn²⁺, SO₄²⁻, HCO₃⁻, F⁻, Cl⁻, NO₃⁻, NO₂⁻ and 8 heavy metals (As, Pb, Cr, Co, Ni, Fe, Cu and Zn). The obtained results for the physical and chemical parameters measured were in agreement with WHO guidelines for drinking water. The ZDM-01(turbidity), ZDD-04(Mn²⁺) and all samples (F⁻) were slightly higher than WHO recommended value. Higher amount of coliform was found at ZDM-01. In addition, the water sources at ZDM-01 and ZDM-03 were identified as NaHCO₃ type water which might be the possible reason for mitigating the kidney stones. This study is the baseline that requires to carry out further studies together with the health professionals in the future to cement the research output.

Keywords

Physicochemical Parameters, Bacteriological Contaminants, Heavy Metals, Sheka WediBsrat

1. Introduction

Water is vital for all known forms of life and plays a substantial role in the well-being of humans. It is mainly used for drinking, cooking, cleaning, agricultural activities, transportation, industrial activities and others. From a biological

perspective, water has many unique properties that are critical for the proliferation of life that set it apart from other substances [1].

Eritrea is found in the Saharan and sub-Saharan region in

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Received: 26 August 2025; **Accepted:** 4 September 2025; **Published:** 25 September 2025



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the horn of Africa which lacks enough rainfall. There are three main drainage systems in Eritrea, which can be distinguished as the: Mereb-Gash and Tekeze-Setit river systems, draining into the Nile river, eastern escarpment and the Bar-ka-Anseba river systems, draining into the Red sea and river systems of a narrow strip of land along the south-eastern border with Ethiopia, draining into the closed Danakil basin [2].

Only one river in the country flows year-round-the Setit River, which also marks the border with Ethiopia. All other rivers are seasonal, carrying water only after rainfall and remaining dry the rest of the year. The country has no natural freshwater surface bodies.. Over the past years, many dams have been constructed mainly in the highland part of the country. The groundwater available in the country does not satisfy the desired quantities and qualities [2]. Many factors affect the underground water including the geological and hydrogeological properties of the rocks and soil. Deep underground waters are not known, borehole (BH) depths are in the range of 20 to 70m. On average around 85% water requirements for domestic, agricultural, industrial and other uses depend on underground water. In Eritrea underground water is mainly affected by annual rainfall [3].

The main problems of this study that research was not carried out in the past to assure the quality of water in these areas for drinking as well as kidney stones remedy. There are domestic wastes surrounding these water sources and there could be possibility that they can be contaminated with fecal coliforms. Therefore, this study could be a base line for further study.

Eritrea, a developing nation in Sub-Saharan Africa, faces many of the common challenges associated with providing water services to its citizens. In Eritrea most of the rural population depends on groundwater resources [4]. According to the World Health Organization (WHO), 80% of diseases are caused by contaminated groundwater. The quality of groundwater is influenced by several factors, including the geology of the aquifer, climatic conditions, and human activities, to be found on the top list [4]. The water contamination of the study areas is possible as more domestic wastes were seen surrounding the water sources.

This study aims to examine the composition and quality of water sources, emphasizing the health risks associated with contaminated water. Waterborne diseases remain a significant public health concern, highlighting the need for thorough quality assessment and risk management. Therefore, this study aims to ensure the quality of drinking water in the two selected areas-Amadr and Sheka Wedi Bsrat-by analyzing its physicochemical parameters and microbiological characteristics using various scientific methods and tools to assess potential contaminants. The number of people using these water sources is increasing. Therefore, the quality assurance of the water sources is required for domestic uses and as kidney stones remedy.

1.1. Microbiological Aspects

The microbiological analysis of drinking water focuses on evaluating the hygienic quality of the supply. Ideally, drinking water should be free from any disease-causing microorganisms and bacteria that indicate fecal contamination. This requires the isolation and enumeration of organisms that indicate the presence of fecal contamination. Indicator organisms include *Escherichia coli*, thermo tolerant coliform bacteria, coliform organisms (total coliforms), *Faecal streptococci* and so on. The presence of *Escherichia coli* clearly indicates fecal contamination; however, in practice, the detection of thermotolerant (fecal) coliform bacteria is considered a suitable alternative [2].

1.2. Physical Aspects of Drinking Water

The pH of natural waters is influenced by the characteristics of the terrain they flow through, and some of the recorded pH values remain within the WHO's acceptable range for drinking water quality, which is between 6.5 and 9.2. pH is one of the most critical factors in assessing the corrosive nature of water - the lower the pH, the greater its corrosiveness. Electrical Conductivity (EC) also shows significant correlations with various water quality parameters, including temperature, pH, alkalinity, total hardness, total dissolved solids (TDS), chemical oxygen demand (COD), and the concentrations of Ca^{2+} , Cl^- , and Fe^{2+} [5]. High conductivity is sometimes associated with more aggressive waters. Conductivity is a key operational parameter for assessing water quality and detecting changes. As per WHO standards, the electrical conductivity (EC) value should not exceed $2000\mu\text{S}/\text{cm}$. [6].

Turbidity is a key physical parameter as it influences both the consumer acceptability of water and the effectiveness of treatment processes. It particularly impacts chlorine disinfection by increasing chlorine demand, shielding microorganisms, and potentially promoting bacterial growth. [7]. The values are given in nephelometric turbidity units (NTU). Ideally, turbidity should be under 5 NTU, as water below this level is generally considered visually acceptable by consumers. Total Dissolved Solids (TDS) refer to the inorganic substances and trace amounts of organic matter dissolved in water. These substances can enter the water supply through leaching from minerals in the aquifer or from various sources such as sewage and urban industrial wastewater. Although the TDS (Total Dissolved Solids) level in water may exceed the WHO standard limit of 1,000 ppm, no harmful effects have been observed so far. [6].

1.3. Chemical Parameters of Drinking Water

Hardness is a crucial property of groundwater from a utility perspective for various uses. It primarily arises from the presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, which are associated with bicarbonates (HCO_3^-), carbonates

(CO_3^{2-}), sulfates (SO_4^{2-}), and chlorides (Cl^-). Among these, Ca^{2+} and Mg^{2+} are the main contributors to hardness. Magnesium, being one of the most abundant elements in nature, plays a significant role in water hardness and can impart an unpleasant taste to the water [8]. Calcium ions (Ca^{2+}) are a major component of many types of rock and are among the most common constituents found in natural waters, with concentrations ranging from zero to several hundred mg/L. Elevated calcium levels in water can result in the formation of solid scale deposits in pipes and kitchenware, as well as increased soap usage. Moreover, excessively high concentrations of Ca^{2+} beyond the permissible limit can lead to precipitation and increased absorption of oxalates into the bloodstream, potentially resulting in the formation of renal kidney stones. The WHO standards for water hardness specify 100 mg/L as the highest desirable level and 500 mg/L as the maximum permissible limit [9]. Total alkalinity (TA) mainly consists of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions, which help stabilize pH levels [5].

Sodium ions (Na^+) are the primary cations in the extracellular fluid (ECF), playing a key role in determining its osmotic pressure and overall volume. The limiting concentration Na^+ in potable water is 2 to 3 mg/L. K^+ ions naturally occur only in the form of ionic salts, and their concentration in water largely depends on the types of rocks the water interacts with. In natural waters, the concentration of K^+ ions remains relatively constant, typically not exceeding 10 to 15 mg/L. [5, 6]. NO_3^- (nitrate) and NO_2^- (nitrite) ions are naturally occurring components of the nitrogen cycle. However, elevated nitrate levels in drinking water-caused by excessive use of agricultural fertilizers, decaying plant matter, domestic wastewater, leachate from refuse dumps, and atmospheric deposition-have become a significant environmental concern [10]. According to the WHO, the maximum allowable limit for nitrate in water is 50 mg/L. Sulfate ions (SO_4^{2-}) naturally occur in water due to the leaching of gypsum and other common minerals. Elevated concentrations of sulfate are often attributed to geological formations rich in sedimentary rocks, particularly gypsum (CaSO_4). According to Meybeck et al., the presence of gypsum is indicative of unpolluted water. Sulfate ions (SO_4^{2-}) in drinking water can also impart a noticeable taste and may contribute to the corrosion of water distribution systems [11]. Fluoride ions (F^-) may be naturally present in water or added during water treatment. A concentration of about 1 mg/L can help prevent tooth decay, but levels exceeding 1.5 mg/L may lead to tooth discoloration, and significantly higher concentrations can result in skeletal fluorosis [12].

1.4. Heavy Metals in Underground Drinking Water

Among various pollutants, heavy metals have garnered significant attention from environmental chemists because of their toxic properties. Although typically found in trace

amounts in natural waters, many heavy metals are harmful even at extremely low concentrations [1]. Heavy metals are chemical elements with a specific gravity at least five times greater than that of water, such as Cd^{2+} , Fe^{2+} , Pb^{2+} , and Hg^{2+} ions. These metals can accumulate in human organs and the nervous system, disrupting their normal functions. Exposure to heavy metal pollution has been linked to diseases affecting the heart, kidneys, and blood [9]. As As^3 ranks first on the ATSDR's list of the most toxic and hazardous substances and is the leading cause of acute heavy metal poisoning in adults. According to WHO guidelines, the maximum permissible concentration of arsenic in drinking water is 0.01 mg/L. While Cr^3 ions are essential micronutrients for both animals and plants, their intake should not surpass 0.05 mg/L. Even low-level exposure to Cr^3 ions may irritate the skin and lead to ulceration. Prolonged exposure can result in damage to the kidneys and liver, as well as impairments to the circulatory and nervous systems [13]. Drinking water contaminated with elevated levels of copper may result in chronic anemia. [6]. The World Health Organization (WHO) recommends a guideline value of 2 mg/L for copper in drinking water. Zinc ions (Zn^{2+}) are essential trace elements involved in various physiological and metabolic processes in many organisms. However, at elevated concentrations, Zn^{2+} ions can become toxic to these organisms [4]. The recommended maximum limit for zinc in drinking water is below 3 mg/L. Cobalt (Co^{2+}) is essential for all animals, serving as a key component of cobalamin (vitamin B_{12}), which is the main biological reservoir of this ultra-trace element [14]. Iron is a vital element in human nutrition. The minimum daily iron requirement ranges from approximately 10 to 50 mg per day [6]. The World Health Organization recommends a maximum allowable concentration of iron in drinking water of 0.30 mg/L. Manganese ions (Mn^{2+}) are essential trace elements for animals, playing roles in numerous enzyme systems and in electron transport. However, prolonged exposure to elevated levels of Mn^{2+} can adversely affect the central nervous system, slowing visual reaction time and impairing hand steadiness and eye-hand coordination [15]. The World Health Organization (WHO) recommends a maximum allowable concentration of 0.5 mg/L of manganese in drinking water.

1.5. Water in Kidney Stone Treatment

Kidney stones are deposits of minerals and salts in the kidney. There are five types of kidney stones but the commonly known types are calcium oxalate, uric acid, cystine and struvite kidney stones. The main cause behind the formation of kidney stones is low intake of water. Fulvic acids in water break down the crystal structure of calcium salts found in kidney stones, forming soluble calcium complexes. This process allows the salts to dissolve and be naturally excreted from the body [16]. Intake of adequate water and reducing salt are the two most common prevention techniques [17]. Crystals of calcium oxalate are disintegrated by humic substances

which are found dissolved in water. One of the most significant properties of humic substances is their ability to form water-soluble complexes with metal ions. Similarly, mineral water rich in bicarbonate (HCO_3^-) helps prevent the formation of uric acid kidney stones by raising urine pH. Bicarbonate, along with calcium (Ca^{2+}), magnesium (Mg^{2+}), and other ions, is a natural component of mineral water. Its intake enhances the body's buffering capacity and serves as a potent alkalizing agent. Therefore, bicarbonate-rich mineral water can support alkalization therapy and contribute to the prevention of kidney stone formation by increasing both urine pH and citrate excretion [18].

2. Materials and Methods

2.1. Description of Study Area

The study areas are found in Zoba Debub which is one of

the six Zobas in Eritrea. Zoba Debub is the most populated region in the country. Amadr is a village found in Debarwa district and Sheka WediBsrat belongs to Mendefera district. These districts are two of the fourteen districts in the Zoba. The number of households that use the water sources from Sheka WediBsrat, Geza Gobo, Amadr I, Amadr II are 300, 370, 400 and 400 respectively. The Sheka WediBsrat and Amadr I have additional users from nearby communities and other cities including Asmara, Mendefera and Debarwa as a medication for kidney stones. The Sheka WediBsrat is usually used for medication because it is found a few hundred meters from the main road that connects Asmara with AdiQuala. It is known that this road is one of the busiest roads in the country. Individuals who are identified as nonresidents of Sheka WediBsrat have to pay some amount of money to take water from it. The water source in Geza Gobo is located only few meters away from the Sheka WediBsrat and Amadr II. The locations of the study areas are shown in Figure 1.

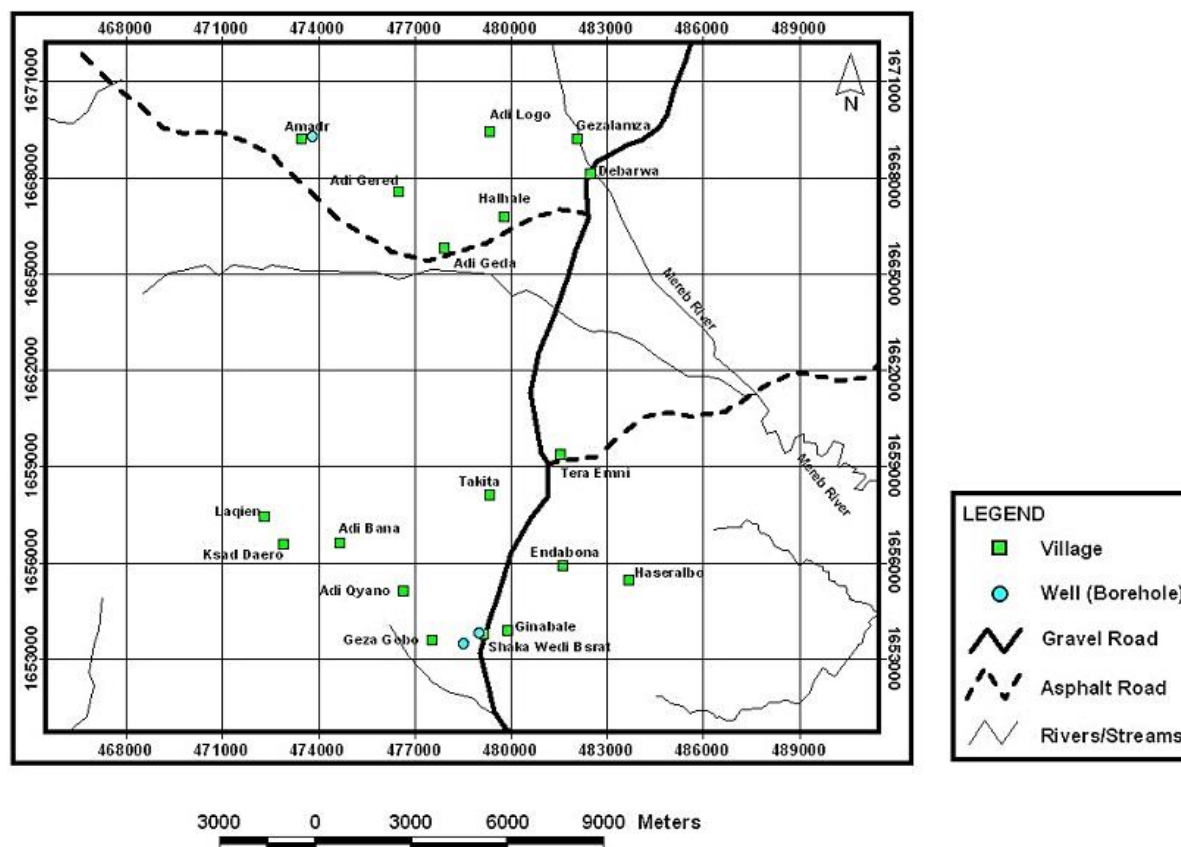


Figure 1. The study areas and nearby villages and towns.

2.2. Preparatory Steps Before Sampling

During the desk study, before visiting the selected areas for sampling, all necessary preparations were made. The instruments were properly calibrated and checked whether they are

in good conditions. The polyethylene bottles were washed thoroughly in order first with detergent, then by nitric acid and finally using deionized water. The Petri dishes that were used for bacteriological analysis were sterilized in an autoclave at 121 °C.

2.3. Sample Collection

The water samples were collected in June from the selected study areas (ZDM-01, ZDM-02, ZDD-03 and ZDD-04) as given in Table 1. The samples were collected in 500mL and 1-liter polyethylene bottles which were thoroughly washed with detergent, dilute HNO₃ and deionized distilled water before use. In the field, the sampling bottles and their respec-

tive caps were rinsed three times with water before sampling. A total of two samples were collected from each source. The samples were numbered from 1 to 4 and labeled against their sources. One sample from each source was acidified with 5mL HNO₃ and stored at 4 °C to avoid the effects of temperature and microorganisms for heavy metal analysis. During sampling, almost all the physicochemical parameters were carried out.

Table 1. Location and Type of the Water Sources.

Sample code	Source name	Number of samples	Source type	Depth	Location
ZDM-01	Sheka WediBsrat	2	BH	38-40 m	Mendefera
ZDM-02	Geza Gobo	2	BH	40 m	Mendefera
ZDD-03	Amadr I	2	BH	40 m	Debarwa
ZDD-04	Amadr II	2	BH	40m	Debarwa

2.4. Chemicals and Materials Used

The chemicals used in this study were PhosVer 3, SPANDS reagent, SulfaVer 4, FerroVer, NitraVer 5, NitriVer 3, citrate type buffer, diphenylarbrozon reagent, mercuric nitrate, bromcresol green pillow powder, methyl red pillow reagent, ManVer 2 reagent, CalVer 2 reagent and EDTA. All the chemicals used were of analytical grades. In this study, the analysis was not carried out in triplicates due to insufficiency of some reagents. The pH and temperature of the samples were measured by using a digital pH meter (Model HI 9828, HANNA instruments, Woonsocket, Rhode Island, USA). The conductivity of the samples was measured using a conductivity meter (Model WTW-Multi 197i 98, WTW, London, UK) and turbidity of the water samples was measured by a turbid meter (Model HI88703, HANNA instruments, Woonsocket, Rhode Island, USA). A flame photometer (Model BMW XP PLUS, BWB TECHNOLOGIES, Newbury, UK) was used for the determination of Na⁺ and K⁺. The analysis of heavy metals was accomplished using an inductively coupled plasma coupled with atomic emission spectroscopy (ICP-AES) instrument (Model PerkinElmer, Waltham, Massachusetts, USA). The spectrophotometric determination of Mn²⁺, SO₄²⁻, NO₃⁻ and NO₂ was done by a spectrophotometer (Model DR 2800, HACH, Loveland, CO, USA).

2.5. Sample Pretreatment

One sample from each source was collected and a total of four samples were used for the analysis. The samples were pretreated first by filtering using a 0.45µm filter paper of a cellulose-acetate membrane type to remove suspensions

which could bring about errors during the analysis and acidified with 5mL HNO₃ and stored at 4 °C.

2.6. Method of Physicochemical Analysis

The physical parameters such as pH, temperature, turbidity, conductivity, TDS, salinity and total hardness were analyzed during the collection of the samples. Total alkalinity was determined by titration using H₂SO₄ and bromcresol green red pillow powder as an indicator. Cl⁻ concentration in a similar manner was established by titrating with mercuric nitrate and diphenylcabazon reagent as an indicator.

2.6.1. Spectrophotometric Analysis

The reagents: FerroVer, SulfaVer 4, NitraVer 5, NitriVer 3, SPANDS, molybdate, PhosVer 3 and sulfide 1 and 2, the concentration of F⁻, SO₄²⁻, NO₃⁻ and NO₂ was analyzed using a spectrophotometer.

2.6.2. Flame Photometer Analysis

A flame photometer was used to determine Na⁺ and K⁺ ions. For Calibration, 300mg/L standard, solution was prepared by taking 12mL of 10,000mg/L from the standard solution and adding 400mL of deionized water.

2.6.3. Heavy Metal Analysis

The analysis of heavy metals was carried out by ICP-AES (Spectro, Perkin Elmer LAS, Germany) at the Standard Global Services (SGS) laboratory in Bisha Mining Share Company (BMSC). The samples were previously pretreated with filtration and acidified with 5mL HNO₃. The pre-acidified samples were digested for re-concentration of

the trace metals before analysis was done.

2.6.4. Bacteriological Analysis

Bacteriological analysis was carried out on two of the four samples. The two samples that were analyzed for this parameter are samples from Amadr and Sheka WediBsrat. The test was carried out with extra caution as bacteriological analysis require extra effort so as to ensure the safety of the person and not to contaminate the samples. The mouth/opening of the sources were first sterilized before sampling using a flame from a cotton ball dipped in alcohol to kill the microorganisms that may be present on the opening of the sources. The samples are then filtered by 0.45 µm paper in diameter. The filter paper is then placed on an absorbent paper that is in turn placed on an Agar media in a previously sterilized petri dish. The petri dishes are placed on an oven at two different temperatures. The petri dish for total coliform test was incubated at 35 °C and that of fecal coliform on 45 °C. After incubation which lasted 18 to 24 hours, the total number of colonies were counted.

2.6.5. Data Collection and Analysis

The collected data were first entered into a Microsoft Excel spreadsheet, where the balance error was calculated. Subsequently, the data were imported into AquaChem-a specialized groundwater software designed for managing, analyzing, and reporting water quality data. This software has then determined the water types and summarized all the values for the parameters measured.

3. Results and Discussion

During the collection of the samples proper handling and care were taken. The physicochemical parameters were measured carefully. The parameters such as turbidity, EC, pH, temperature, salinity and total alkalinity were carried out in the field and the total hardness, Na⁺, K⁺, mg²⁺, Ca²⁺, SO₄²⁻, NO₃⁻ and NO₂ levels were measured in the laboratory of WRD in Asmara. The results obtained for each measurement are summarized in Table 2.

Table 2. Results of Physicochemical Parameters.

Water Sources					
Parameters	ZDM-01	ZDM-02	ZDD-03	ZDD-04	WHO limit
pH	7.96	6.15	6.98	7.27	6.5-9.2
Temperature (°C)	22.9	25.6	24.5	27.4	25
EC (µs/cm)	595	832	730	787	2000
Turbidity (NTU)	6.06	0.17	0.95	0.13	<5
TA (mg/L)	240	300	272	256	300
TA (mg/L)	28	304	136	192	500
Na ⁺ (mg/L)	124.1	51	93.6	88.8	200
K ⁺ (mg/L)	0.80	0	2.7	0.7	12
Mg ²⁺	6.7	6.2	5.3	6.5	150
Ca ²⁺ (mg/L)	36	32	27.2	35.3	200
Mn ²⁺ (mg/L)	0.2	0.1	0.1	1.2	0.5
F ⁻	2.2	1.9	1.6	2.8	1.5
Cl ⁻	52.5	23.5	35.2	29.6	600
NO ₂ ⁻ (mg/L)	0.004	0.006	0.004	0.14	3
NO ₃ ⁻ (mg/L)	3.5	21	1.7	13.5	50
HCO ₃ ⁻	553.2	297.9	448.8	348.7	50
SO ₄ ²⁻ (mg/L)	20	13	44	55	300

3.1. Physical and Chemical Parameters

The pH ranged from slightly acidic to slightly basic (6.15–7.96), remaining within the WHO's recommended guidelines for drinking water (6.5–9.2), except at site ZDM-02, which recorded a pH of 6.15.

The results show that ZDM-01 and ZDD-03 have relatively lower EC values than the two other samples. This indicates that these two sites have a smaller number of dissolved ions. Generally, the EC values for all of the samples were lower than the WHO limit.

According to WHO, the values of total alkalinity should be less than 300mg/L. The results for the samples ranged from 240 to 300mg/L. Only ZDM-02 had a value which coincide with the maximum value given by WHO, but the others were within the guided limit. Since the alkalinity of groundwater primarily arises from carbonates and bicarbonates, a higher alkalinity value indicates an elevated level of bicarbonates. All the water sources exhibit high concentrations of bicarbonate ions, classifying them as bicarbonate-type waters.

The WHO establishes that the turbidity of drinking water should not be more than 5 NTU and if all possible below 1 NTU. Only ZDM-01 was found to exceed the permissible limit, in which its value was 6.06 NTU. While turbidity itself does not pose a direct health risk, it serves as a key indicator of potential contaminants that could impact an individual's health. This may be the reason that the microbial test was found 30 colonies for Fecal and 50 colonies for total coliform in this sample. But the other three samples lie within the desired limit which is <1 NTU.

The ZDM-02 is medium water and the remaining samples are soft water. Soft water is comfortable for drinking and it has higher domestic use which does not consume soap.

HCO_3^- assists in opening peripheral blood vessels and can improve blood circulation. HCO_3^- concentration was above the WHO limit and HCO_3^- in the analyzed samples was found to be 297.9–553.2mg/L. Cl^- acts as an essential electrolyte and maintains homeostasis, and transmits action potential in neurons. According to WHO standards the amount of Cl^- in a potable water has required to be <600mg/L. All the examined samples were having Cl^- concentrations in the required WHO limit (23.5–52.5mg/L). The concentrations of NO_3^- in the samples range from 1.7 to 21mg/L and the WHO limit is 50mg/L. The NO_2^- values range from 0.004 to 0.014mg/L and the WHO limit is 3mg/L. The sources of these ions could be from the nearby agricultural activities and add value to the quality of the water sources. According to WHO standards the amount of F^- in a potable water should be <1.5mg/L. The F^- concentration was found to be slightly above the WHO standard limit (1.6–2.8mg/L).

If the concentration of SO_4^{2-} exceeds 250mg/L, it can give water a bitter or medicinal taste, making it unpleasant to drink [8]. The SO_4^{2-} level for the samples of Shekha Wedi Bsrat (ZDM-01 and ZDM-02) were slightly lower as compared to

the samples of Amadr (ZDD-03 and ZDD-04) as shown in Table 2. This potential difference could be due to the geological location of the sites. However, the results for SO_4^{2-} in all the samples were extremely low as compared to the WHO desirable limit.

According to WHO standards the amount of mg^{2+} in a potable water required to be <150mg/L. Based on the analysis made, the mg^{2+} concentration of all samples was within the recommended guide line of WHO (5.3–6.7mg/L). Mn^{2+} level exceeding 0.1mg/L is undesirable for drinking but its maximum permissible limit is 0.5mg/L. The results obtained for the samples range from 0.1–1.2mg/L. The results revealed that ZDD-04 had Mn^{2+} value of 1.2mg/L which has exceeded the maximum permissible limit (0.5mg/L). Thus, this water source is not potable. Prolonged exposure to high levels of Mn^{2+} can impair the central nervous system, slow visual reaction time, reduce hand steadiness, and disrupt eye-hand coordination. Therefore, consuming water from this source may pose health risks to individuals.

The concentration of Na^+ and Ca^{2+} ions were within WHO limits in the range of 51–124.1mg/L and 27.2–36mg/L, respectively (Figure 2). The high total alkalinity and low total hardness contribute to that these ions are very important parameters that play a role in the kidney stone remedy.

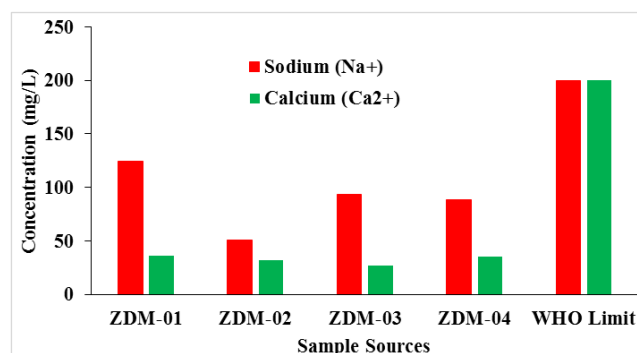


Figure 2. The comparison of Na^+ and Ca^{2+} levels with WHO limits.

3.2. Heavy Metals Analysis

Among various pollutants, heavy metals have garnered significant attention from environmental chemists due to their high toxicity. Although they typically occur in trace amounts in natural waters, many are harmful even at extremely low concentrations.

Some heavy metals such as Fe^{2+} , Cu^{2+} , Mn^{2+} , and Zn^{2+} are nutritionally important in trace amounts for a healthy life. Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues. As per this study is concerned analysis of 8 (eight) heavy metals were analyzed at the laboratory of BMSC and all the heavy metals were found to be in agreements within the WHO limit (Table 3).

Table 3. Results of Heavy Metal analysis inmg/L.

Heavy metals	ZDM-01	ZDM-02	ZDD-03	ZDD-04	WHO LIMIT
Co ²⁺	0.00067	0.00088	0.00028	0.00050	0.01
Cr ³⁺	0.00123	0.00300	0.00148	0.00124	0.05
Cu ²⁺	0.00166	0.00127	0.00161	0.00160	2.00
Fe ²⁺	0.00081	0.00013	0.00010	0.00001	0.30
Ni ²⁺	0.00102	0.00109	0.00185	0.00122	0.07
As ³⁺	0.00086	0.00064	0.00047	0.00056	0.01
Pb ²⁺	0.00057	0.00086	0.00183	0.00195	0.01
Zn ²⁺	0.00780	0.00704	0.00694	0.00874	3.00

3.3. Microbial Test

The microbiological test will identify total coliforms (a type of bacteria) and fecal coliforms in drinking water. The fecal coliform test (most commonly tested for thermo tolerant coliforms or *Escherichia coli*) will indicate the level of fecal contamination in the water and how safe the water is to drink. The result after culturing was found to be 30 colonies for fecal and 50 colonies for total coliform in ZDM-01 and zero for both tests in ZDD-03. During the time of sampling, ZDM-01 was found lacking proper hygiene, as dung of donkeys used to carry water was found on the base of the hand-pump. There was a small visible crack at the base of the hand-pump that could lead for contamination of the water by the dung. Since some of the total coliform are excreted in the feces of humans and animals this could be the possible reason behind the contamination of this site.

3.4. Water Type Determination

The water type of each sample was determined with the help of a software, AquaChem (AquaChem, Knoxville, TN, USA). The two samples (ZDM-01 and ZDD-03) which were believed to be alleviating kidney stones were found to be of Na-HCO₃ type. But the other two water samples were found to be Ca-Na-Mg-HCO₃ (ZDM-02) and Na-Mg-Ca-HCO₃ (ZDD-04) water types. The results have shown that, the sources associated with the controversy of alleviating kidney stones had a much more similar water type than the other two sites.

Bicarbonate (HCO₃⁻) induces metabolic alkalosis, which results in elevated urinary pH and increased citrate excretion. Citrate functions as an inhibitor of calcium oxalate crystallization by forming a highly soluble complex with calcium, thereby reducing the saturation of calcium salts in the urine [19].

4. Conclusion

The central aim of this investigation was to evaluate the quality of two subterranean water sources located in Shekha WediBsrat and Amadr within Zoba Debub, both of which are traditionally regarded as having therapeutic properties. Analytical results revealed that the concentrations of all assessed physicochemical parameters and heavy metals were within the permissible limits set by the WHO for potable water, confirming their safety for human consumption. Furthermore, the two sources designated ZDM-01 and ZDD-03 were classified as sodium bicarbonate (NaHCO₃) type waters. This classification supports local beliefs that these waters may aid in the treatment of kidney stones. Contemporary scientific literature corroborates the therapeutic potential of Na-HCO₃-rich water, particularly in managing kidney stones composed of calcium oxalate and uric acid. Bicarbonate ions (HCO₃⁻) promote metabolic alkalosis, which elevates urinary pH and enhances citrate excretion. Citrate acts as an inhibitor of calcium oxalate crystallization by forming a highly soluble complex with calcium, thereby reducing the supersaturation of calcium salts in urine. The elevated pH levels observed in these samples may facilitate such complexation, offering a plausible explanation for their traditional medicinal use. In light of these findings, it is imperative to undertake comprehensive physical and chemical analyses in collaboration with healthcare professionals and to implement systematic monitoring protocols for these water sources.

Abbreviations

SGC	Standard Global Services
BMSC	Bisha Mining Share Company
WHO	World Health Organization

Acknowledgments

The authors gratefully acknowledge the Department of Chemistry, Mai Nefhi College of Science, for providing the necessary support. We also extend our sincere thanks to the Department of Water under the Ministry of Land, Water and Environment, as well as Bisha Mining Share Company, for their invaluable and unwavering assistance.

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Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Data Availability Statement

This statement does not apply to this article.

Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Conflicts of Interest

The authors declare no conflicts of interest.

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