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COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

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DEPARTMENT OF CHEMISTRY

DETERMINATION OF SELECTED PHYSICOCHEMICAL AND MINERAL CHARACTERISTICS OF DRINKING WATER IN ANASORA DISTRICT, GUJI ZONE, OROMIA REGIONAL STATES, ETHIOPIA

By: DEREJE JANBOARARSO (PGChemK/007/11)

ADVISOR: MELAKU ZIGDE (ASS. PROFESSOR)

OCTOBER, 2024

HAWASSA, ETHIOPIA

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A MASTER THESIS SUBMITTED TO THE DEPARTMENT OF CHEMISTRY, COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCE, SCHOOL OF GRADUATE STUDIES, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN CHEMISTRY

ADVISOR: MELAKU ZIGDE (ASS. PROFESSOR)

OCTOBER, 2024

HAWASSA, ETHIOPIA

DECLARATION

I hereby declare that this MSc thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis/dissertation have been duly acknowledged.

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LISTS OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
AAS	Atomic Absorption Spectroscopy
APHA	American Public Health Association
ATSDR	Agency for Toxic Substances and Disease Registry
BIS	Bureau of Indian Standards
EC	Electrical Conductivity
EDTA	Ethylenediammine Tetra Acetic acid
EEPA	Ethiopia Environmental Protection Agency
ES	Ethiopian Standard
FAAS	Flam Atomic Absorption Spectrometer
FAO	Food and Agricultural Organization
TA	Total alkalinity
TDS	Total Dissolved Solids
TH	Total hardness
UNEP	United Nations Environmental Program
US-EPA	United State Environmental Protection Agency
UNICEF	United Nations Children's Fund
WHO	World Health Organization
PH	Hydrogen power

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ABSTRACT

Drinking water should be free unwanted constituent, contaminant, or impurity and fulfil quality requirements (desirable and permissible limits) recommended national and international organizations. This study was done to determine the levels of selected physicochemical parameters (temperature, pH, Electrical Conductivity, Total hardness, Total Alkality, and chloride), and minerals such as (Ca, Mg ,Cr and Pb), trace elements (Cu, Mn, Ni, and Co) in drinking ground water samples sampled from selected Kebeles such as Bube Korsa, Hiyo Komele, and Irba Buliyo of Ana Sora district, Guji zone, Oromia regional state, Ethiopia. The temperature, pH, electrical conductivity, and TDS were measured using an AD8000 pH/mV/EC/TDS/Temp meter; TH, TA, and chloride were determined by titration method, while the mineral content was determined by flame atomic absorption spectrometry (FAAS). The average values of the physicochemical parameters investigated in this study were found to be in the range: temperature (20.8 – 23.1) °C, EC (3.7 – 23.7) μS/cm, TDS (8.5 – 12.8) mg/L, TH (14.7 – 42.4) mg/L, TA (23.3 – 38.3) mg/L and chloride (2.3 – 3.8) mg/L. The average concentrations of the minerals were found to be in the range of temperature: Ca (2.32 – 9.62) mg/L, Mg (11.9 –24.6) mg/L, and Cu (0.13 – 0.30) mg/L. Metals such as Mn, Ni, Co, Cr, and Pb were found to be below the detection limit of the instrument. The accuracy of the method of recovery experiment the analysis was evaluated by analyzing the digest of the spiked samples. The recoveries of the metal were in the range of 96.0to 110.0%.One-Way-ANOVA analysis showed that there were significant variations ($p < 0.05$) in the physicochemical parameters and metals investigated among the drinking groundwater samples. However, all the values of the physicochemical parameters investigated were found to be within the acceptable standard specified in Compulsory Ethiopian Drinking Water Specifications. Therefore, the drinking ground water supplied to the community in Ana Sora district was deemed to be safe for human consumption according to the selected parameter and, mineral set as standard.

Keywords: Ana Sora, Guji zone, drinking ground water, physicochemical, minerals

1 INTRODUCTION

1.1 Background of the Study

Water is vital for human health and well-being. Water is needed in all life activities, especially for domestic and agricultural activities. Safe water represents water that is affordable, available in the required quantity as a beverage, for food preparation, and for private hygiene and washing [1]. Safe water also signifies water that doesn't pose any significant health risk and it constitutes a major resource to fulfil the needs of basic hygiene that are necessary for curbing water-related diseases. However, the availability of safe water is restricted [2]. About, 3.0% of the whole globe's water is considered fresh water, and 2.97% of it is locked up in icecaps and glaciers. Only 0.03% of water is obtainable as surface and groundwater for human use [3]. In addition, the supply and distribution of the planet’s freshwater worldwide are uneven.The availability of an adequate safe water supply is essential to human existence and it is recognized as a fundamental right of human beings that is placed next to oxygen as crucial for the existence of life. However, access to a clean, safe, and adequate drinking water supply is still scarce in many developing countries and poses health risks associated with water-related diseases [4]. As a result, more than 700 million people, mostly living in developing countries, have no access to improved water sources and sanitation facilities [5].Although Ethiopia is the water tower of East Africa, water is still inaccessible in most parts of the country. Moreover, water quality is poor and often contaminated by human and animal faeces [6–9]. As a result of limited improved water availability, most rural population relies on unimproved water sources. It is estimated that about 57% of households have access to an improved drinking water source, with a higher proportion among urban residents (93%) than among rural residents (49%) showing a big disparity between urban and rural households in terms of access and types of services. Moreover, as access to improved sanitation facilities is very limited in rural areas, the majority of households defecate in the bush or open fields [10]. A study showed that only 42.2% of household has access to improved drinking water sources and low status using improved sanitation facilities in the Oromia region, Ethiopia [11].

According to WHO/UNICEF [10], improved drinking water sources are defined by the nature of their design and construction, have the potential to deliver safe water, and include piped water, boreholes or tube wells, protected dug wells, protected springs, rainwater, and packaged or delivered water. Drinking water sources such as ponds, lakes, rivers, and open-dug wells are considered unimproved. In addition, drinking water sources that are poorly constructed or do not have any engineered facilities such as spring boxes, borehole capping, and wells are also considered as unimproved [12]. The use of unimproved water sources usually associated with the presence of indicator bacteria and elevated levels of harmful substances or pollutants [10, 13–18] could cause water contamination and lead to several diseases such as cholera, dysentery, salmonellosis, and typhoid [19, 20]. Waterborne diseases associated with these are attributed to the death of millions in developing countries every year [21]. According to World Health Organization (WHO), more than 16% of populations across the world have a shortage of safe drinking water sources [22].

As a result, death recorded to poor quality of drinking water is very high in developing countries (99.8%) [23], and about 1.7 million losses and 54.2 million disability-adjusted life-years worldwide are attributable to unsafe water and poor sanitation and hygiene problem [24]. Additionally, the study indicated that about one-fourth of the world's population used unsafe water in 2010 and more than one-six worlds’ population use water from water sources with substantial hygienic hazards [4].

In Ethiopia, from surface to improved sources, 35 million people have gained access to water from piped systems, protected hand pumps, and springs. So, Ethiopia achieved the drinking water Millennium Development Goals (MDG) target of 57 percent, successfully halving the number of households without access to improved drinking water since 1990. In doing so over 52 million people in Ethiopia now have access to an improved drinking water source (within 1.5 kilometers) as compared to only 6 million people in 1990 [25]. This achievement is primarily the consequence of significant improvements in access to drinking water supplies in rural areas. However, Ethiopia has a significant challenge to increase the water quality coverage to achieve the sustainable development goals (SDGs) aim at universal access to safe water supply and sanitation [26]. Safe water supply includes the quality of water at the sources or drinking water must be free from pathogens and elevated levels of harmful substances at all times. So, the quality of drinking water can be compromised when it is contaminated by waste from various sources. The sources of water contamination could be geological, industrial, and agricultural activities. These contaminants are further categorized as microorganisms, inorganics, organics, and radionuclides. They can affect the quality of water and then human health upon consumption before proper treatment [27]. Therefore, water quality control is a major strategy program in numerous parts of the world [28].

Several scientific processes and methods have been developed to assess physicochemical parameters and biological characteristics in drinking water [29]. This physicochemical parameter includes pH, turbidity, Electrical conductivity (EC), total suspended solids (TSS), total dissolved solids (TDS), and minerals. These parameters can affect the drinking water quality if their values are higher than the standard values set by the WHO and other regulatory bodies [29].

This study focuses on the assessment of the levels of selected elements and physicochemical parameters in drinking ground water in Ana Sora district, Guji Zone, Oromia regional state Ethiopia. Furthermore, the levels of the selected physicochemical parameters and minerals will be compared with national and international guidelines and standards for drinking water quality.

1.2 Statement of the Problem

Drinking water from any source and being subjected to any treatment process may reasonably be expected to contain a large range of constituents. Some of these constituents are considered essential for human health, while others are considered dangerous contaminants. However, surface water is more likely than groundwater to be contaminated with microbiological pathogens from human and animal excreta, which is the most common cause of water pollution in the rural East African Region. However, groundwater may become unpotable as a result of contact with some minerals in the soil or may be contaminated by deep waste pits and latrines located close to the well or springs, etc.

Furthermore, groundwater is more likely to contain hazardous chemical contaminants, such as arsenic, fluorides, and nitrates from natural processes that can contribute to higher levels of metals and other chemicals that can harm human health and causes damage to internal organs of the human body (kidney, liver, and brain) [30]. Hence, assessing the physicochemical and mineral composition of drinking water in Ana Sora district, Guji Zone is crucial because the community uses groundwater as one of the major sources of drinking water without any form of treatment. The community in the woreda obtains their drinking water from ground water point sources located in different parts of the town. As there is no research conducted to assess the physicochemical quality of the water sources, this study intends to determine the levels of the selected physicochemical parameters and elements in drinking water samples collected from three kebeles inAna Sora district, Guji Zone, Oromia regional state, Ethiopia.

1.3 Objective of the study

1.3.1 General Objective of the Study

The general objective of the study was to determine the levels of selected elements and physicochemicalparameters of drinking water samples collected from three kebeles such as Bube Korsa, Hiyo Komele, and Irba Buliyoin Ana Sora district, Guji Zone, Oromia regional state, Ethiopia.

1.3.2 Specific Objective of the Study

The specific objectives of the study are;

- To determine physicochemical parameters such as temperature, pH, electrical conductivity, total dissolved solids, total hardness, total alkalinity and chloride in drinking water samples collected from three kebeles in Ana Sora district, Guji Zone, Oromia regional state, Ethiopia.
- To determine the concentration of selected major elements (Ca, and Mg), trace elements (Mn, Fe, Ni, Cu, and Co) and heavy metals (Cr, Pb, and Cd) in drinking water samples collected from three kebeles in Ana Sora district, Guji Zone, Oromia regional state, Ethiopia.
- To compare the levels of the selected elements and physicochemical parameters with national and international guidelines for drinking water quality.
- To compare the levels of the selected elements and physicochemical parameters among the drinking water samples under study.

1.4 Significance of the Study

The study would focus on the determination of selected physicochemical parameters and minerals in samples collected from three kebeles in Ana Sora district, Guji Zone, Oromia regional state, Ethiopia. As there is no study conducted about the selected physicochemical parameters and minerals in drinking water samples collected from three kebeles in Ana Sora district, the findings of the study would help:

- To inform the concerned organization about the results of the study for them to take action, if necessary, for the well-being of the society
- To suggest ways to improve the quality of the drinking water in the woreda if there is any quality concern regarding drinking water sources under studied.

- To provide useful baseline data about the levels of the selected physicochemical parameters for further studies.

2 LITERATURE REVIEW

2.1 Introduction

Water is one of the essential requirements for life. All living things need water for their survival and without it, life cannot survive. Specifically, domestic water–that is, water used by a household for drinking, food preparation, and hygiene–is necessary for human life. Without water, life cannot be sustained beyond a few days, and inadequate water supplies lead to the spread of disease. Water is a critical resource and about three-quarters (more than 70%) of our world is covered with water most of Earth's water is not available for human use because only less than 1% of it is available as fresh water and about 75% of the freshwater is located in glaciers and the polar ice caps [31]. As a result, this freshwater is unavailable for man's use. In addition, the remaining fresh water is loping countries, lack safe drinking water. Apart from the scarcity of water, there are many other challenges in providing a safe, adequate, and reliable water supply in many parts of the world.

2.2 Use of Water

Water is used in many ways: for domestic purposes such as drinking, in the industry for the production of manufactured goods, automobiles, and gasoline, in commercial establishments (such as hotels and restaurants), in farming (for agriculture such as growing food and animal-rearing), for emergency uses such as fire-fighting, for removing or diluting wastes, construction of highways and buildings, and power generation and so on. Water is essential for the proper functioning of the body. It has an important place in performing many vital activities such as circulation, excretion, and reproduction [5], 80–90% of our blood and 75% of our muscles are made up of water [32]. Water plays a critical role in the functioning of the human body. It supports digestion of food; absorption, transport, and use of nutrients; and elimination of toxins and wastes from the body [33]. In addition to its indispensability for biological survival, water is of crucial importance to business and industry [34].

Although the total amount of water is constant and is a function of precipitation, the water demand has increased rapidly in the last few years. As compared to the amount of water required for all purposes such as food production, manufacturing, irrigation, and construction of highways and buildings, water required for domestic purposes–that is, water used by a household for drinking, food preparation, and hygiene–is small. However, water required for domestic purposes must be safe for drinking and other household uses. Especially, drinking water must be safe, affordable, and accessible and be free from pathogenic (disease-causing) micro-organisms (tiny living organisms that you can see only with a microscope), and free from chemical and physical contaminants that constitute a danger to a person's health [20]. It must also be free from color and odor. In addition, the water must be within safe physical reach, in or near the house, school, or health facility. According to the WHO/UNICEF Joint Monitoring Programme [35], the water source has to be within 1000 m of the home, and collection time should not exceed 30 minutes.

2.3 Types of Freshwater Sources

The three main water sources used for domestic purposes (the origin of the water and also the place where people get their water like spring, piped supply to household tap, water point, well, etc.) are groundwater, surface water, and rainwater. In arid regions where seawater is accessible (such as in the Middle East), desalination (the removal of salts from water) is used to generate drinking water. Another potential source of water is treated wastewater. Particularly, in urban areas, the water supply originates either from a spring (a point where groundwater emerges at the surface of the ground and it may flow throughout the year or only at times), from where the water can be piped to consumers or a well or borehole that may supply individual residences or a large number of houses where the water is delivered through a network of pipes or from a water treatment plant. Surface water from rivers and lakes may be abstracted directly or stored in a reservoir created by building a dam across a river and the surface water is treated in a water treatment plant before being distributed to consumers. In larger towns and cities, surface water is treated in a water treatment plant before being distributed to consumers.

Water sources can be classified as protected or unprotected. Protected sources are covered by stonework, concrete, or other materials that prevent the entry of physical, chemical, and biological contaminants.Unprotected sources are those with no barrier or other structure to protect the water from contamination. All surface water sources, such as lakes, rivers, and streams or poorly constructed wells, are examples of unprotected sources. Water from unprotected sources cannot be considered safe to drink unless it has been treated. In addition, WHO and WHO/UNICEF joint monitoring program [10]categorized sources of drinking water as improved and unimproved, which are broadly equivalent to 'protected' and 'unprotected'. According to the WHO/UNICEF joint monitoring program [10], improved drinking water sources are defined by the nature of their design and construction, have the potential to deliver safe water, and include piped water, boreholes or tube wells, protected dug wells, protected springs, rainwater, and packaged or delivered water. Springs and wells are considered improved sources of water if they are constructed and used in such a way that they adequately protect the water from contamination, especially by fecal matter. Spring or well water is generally used with minimal or no treatment. An unimproved drinking water source is one that by the nature of its construction does not adequately protect the source from outside contamination, particular with fecal matter [36]. Unimproved drinking-water sources include an Unprotected (dug) well; unprotected spring, cart with a small tank or drum; tanker truck-provided water, surface water (river, dam, lake, pond, stream, canal, irrigation channel), and bottled water (because of potential limits on the quantity of water available to a household through this source, not the quality) [37-40]. Surface water is an unimproved source and will require some form of treatment in a water treatment plant before it is safe to use for drinking.

In addition, drinking water sources that are poorly constructed or do not have any engineered facilities such as spring boxes, borehole capping, and wells are also considered as unimproved [12]. However, groundwater, the greatest source of available fresh water, is believed to be comparatively much clean and free from pollution than surface water because groundwater is filtered as it seeps through the soil. Groundwater is a major source of fresh water for the world and is used to carry out human activities apart from industrial applications. Approximately one-third of the worldwide population depends on groundwater for drinking usage [41].

Groundwater is a major source of drinking water, and it can be vulnerable to contamination due to agriculture, urban, and industrial development. However, in Ethiopia, rural residents use boreholes or spring water for their domestic and drinking consumption without strict water quality monitoring [41, 43]. Groundwater, the greatest source of available fresh water, is believed to be comparatively much clean and free from pollution than surface water because groundwater is filtered as it seeps through the soil. However, groundwater can become contaminated naturally [34] or because of numerous types of human activities; residential, municipal, commercial, industrial, and agricultural activities can all affect groundwater quality [44, 45]. Thus, groundwater may require treatment for the removal of those man-made surface contaminations such as bacteria and chemicals before it is usable.

2.4 Water Source Pollution

Water quality is closely linked to the surrounding environment and land use. Usually, water could be never pure and may be affected by agriculture, urban, industrial, recreation, and so on [44]. The quality of water plays a prominent role in promoting both the standard of agricultural production and human health. The modification of natural stream flows and the weather or climate change can also have a major impact on water quality. A possible contamination source that carries threats to drinking water quality is open field defecation, animal wastes, plants, economic activities (agricultural, industrial, and businesses), and even wastes from residential areas as well as flooding situation of the area. Any water sources, especially older water supply systems, hand-dug wells; pumped or gravity-fed systems (including treatment plants, reservoirs, pressure break tanks, pipe networks, and delivery points) are vulnerable to such contamination. Particularly systems with casings or caps that are not watertight are most vulnerable. This is particularly true if the water sources are located close to surface runoff that might be able to enter the source. The additional way by which pollution reaches and enters a water supply system is through overflow or infiltration by floodwaters and inundation of waters that commonly contain high levels of contaminants [46]. Furthermore, groundwater pollution depends on the inherent hydro geological property of the site, agricultural land use, and cultivation practices [47]. Contamination of groundwater can result in poor drinking water quality, loss of water supply, high clean-up costs, high costs for alternative water supplies, and/or potential health problems.

Another situation that leads to the contamination of water sources is the inappropriate disposal of animal waste, garbage, and liquid waste in the surrounding fields [5, 48, 49].Water can be contaminated at any point in the supply system [49]. Although protection of water supply from contamination is the first line of defence, water source protection is the best method of ensuring safe drinking water [16]. Thus, a continuous surveillance and monitoring system of water sources should be in place to ensure the provision of safe and good-quality drinking water for rural communities [19]. The provision of a safe and adequate water supply for the population has far-reaching effects on health, productivity, and quality of life [50]. Therefore, this study is designed to assess the selected elements and physicochemical parameters in drinking water sources used in Ana SoraWoreda, Guji Zone South Oromia Ethiopia.

2.5 Heavy Metals Contamination of Water

Heavy metal is a general collective term that applies to the group of metals and metalloids with an atomic density greater than 4g/cm^3. Heavy metals are important components of building materials, vehicles, appliances, computers, highways, bridges, railroads, airports, electrical utilities, and food production and distribution. Natural and consumer products contain small concentrations of different heavy metals. Heavy metals in subsurface environments come from natural and anthropogenic sources. Natural sources include weathering of minerals whereas, anthropogenic sources include fertilizers, industrial effluent, and leakage from service pipes. As water travels over the surface of the land or in the subsurface, it may cause naturally-occurring mineral dissolution and can pick up many substances generated by human activities. Pollutants that may be present in a water source before treatment include a variety of inorganic contaminants, pesticides, herbicides, toxic heavy metals, and organic chemical contaminants [51]. In addition, point source water contamination may arise from factories, wastewater treatment facilities, and other sources that are discharging pollutants into water sources while non-point source water contamination is more complex to identify because it cannot be reversed back to their particular location. Non-point sources include runoff sediments, fertilizer, chemicals, and animal wastes from farms, fields, construction sites, and mines. Landfills are also considered a non-point source of pollution; if substances are transported from the landfill into water supplies, wastes in landfills may run into a different source of drinking water either groundwater or surface water [52, 53].Heavy metals are released into the ecosystem from geogenic (natural alteration of the mineralized zone) and anthropogenic (mining, agrochemicals, and industrial effluents) activities [54, 55]. This makes water bodies the most vulnerable environmental aspect to heavy metal contamination [56, 57]. A study showed that Industrial and agricultural activities are the major contributors to contamination [58]. Investigations of heavy metals in water help in determining the status and contamination load [59]. Therefore, regular quantification of heavy metals is crucial to identify temporal variations in aquatic ecosystems [60].Moreover, the nutrients and agrochemicals applied to the cultivation area, adjacent to water bodies, may also reach via overland flows and subsurface flows during precipitation events or at a slower rate reach surface water bodies through groundwater discharge.

2.6 Water Quality Parameters

Water quality parameters are classified into three aspects such as physical, chemical, and biological characteristics of water in association with the set of standards. These parameters are directly connected to the safe use of water for various purposes. Water quality parameters deliver important information about the fitness of a water body. These limits are used to find out the quality of water for drinking purposes [61]. Analysis of water quality parameters is the basis for water quality monitoring. Different analytical procedures or methods have been developed to measure quantitatively water quality parameters. In this study, the selected physicochemical parameters will be determined following the methods of APHA [62] and WHO [63].

2.7 Description of Selected Water Quality Parameters

According to the World Health Organization (WHO), the priority parameters that should be considered in any drinking water quality assessment are those that have the greatest health impact and are most commonly detected at significant concentrations in drinking water [64]. Thus, fifteen parameters were selected in this study Temperature, pH, electrical conductivity (EC), turbidity, total dissolved solids (TDS), total hardness (TH), Total Alkalinity (TA), chloride (Cl^-), calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), cobalt (Co), chromium (Cr), nickel (Ni) and lead (Pb).

2.7.1 Temperature

Assessment of water temperature is perhaps the most simple. Still, it gives a good estimate of the water quality since it affects its biological, chemical, and physical properties. The amount of dissolved oxygen, photosynthesis activity, rate of chemical reactions, aquatic organisms' sensitivity to pollution as well as their metabolic rate are some examples of how temperature affects the water. The growth and decomposition of organic matter and microbial growth increase with an increased temperature. The temperature will be measured using a portable Multi-parameter.

2.7.2 pH

pH is a measure of the activity of hydrogen ions in an aqueous solution. It represents the balance between hydrogen ions and hydroxide ions. The pH value of water can affect plant growth, irrigation equipment, and drinking quality [65, 66].pH will be measured using a portable Multi-parameter.

2.7.3 Electrical Conductivity (EC)

Salts, together with other dissolved substances are what constitute TDS in water. Salts are chemical compounds of carbonates, chlorides, sulphates, nitrates, potassium, magnesium, calcium, and sodium [67]. The content of these compounds is usually determined by the underlying bedrock. In areas where evaporation exceeds precipitation salt concentrations are expected to be high. This is especially true for arid and semi-arid areas, like Ethiopia. The ability of water to conduct an electrical current is directly proportional to the number of solids in the solution. Saltwater has many solids (charged particles) in solution and is, therefore, a good conductor of electrical currents, while freshwater is a poor conductor. Electrical conductivity will be measured using a portable Multi-parameter.

2.7.4 Total Dissolved Solids (TDS)

Water has the aptitude to dissolve an extensive variety of inorganic and organic mineral deposits or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates, etc. These mineral deposits formed undesirable taste and diluted color in the appearance of water. No contract has been developed on bad or an optimistic effect of water that exceeds the WHO standard of maximum permissible level is 1,000 ppm. TDS in drinking water originates in numerous ways from sewage and urban industrial wastewater etc. Hence, the TDS test is mostly an indication to control the general quality of the water [31]. In this study, TDS will be determined using the gravimetric method [62, 68].

2.7.5 Total Alkalinity

Alkalinity is the measure of an aqueous solution's buffer capacity, the ability to neutralize the acid. Alkalinity is primarily due to the presence of one or more ions in water including hydroxides, carbonates, and bicarbonates. It can be defined as the capacity to neutralize the acid. A moderate concentration of alkalinity is desirable in most drinking water supplies to stable the corrosive effects of acidity. Extremely high alkalinity values in drinking water may cause bad odor and taste as well as the drying of the skin, but generally, there is no health risk associated with it [69]. The alkalinity of water samples will be determined by Titrimetric Method.

2.7.6 Total Hardness

Hard water is mainly described with high mineral contents that are usually not dangerous for humans. It is frequently measured as calcium carbonate ($CaCO_3$) because it contains mainly calcium and magnesium carbonates which are the most dissolved ions in hard water. Magnesium, iron, manganese, aluminium, and zinc are other cations that can contribute to hardness [66]. Usually, water gets hard due to mineral leaching from soil and aquifers. Thus falling rain and distilled water can be referred to as "soft". Water with high levels of calcium hardness may promote its precipitation and scale formation. Hard water may also affect soils which indirectly impacts plants and their growth [67]. Public acceptability of the degree of hardness of water may be different considerably from one community to another. The degree of hardness of drinking water has been classified in terms of its equivalent $CaCO_3$ concentration. As a result, water can be classified into soft, moderately hard, hard, and very hard based on hardness values [70, 71, and 72].

2.7.7 Chloride(Cl^-)

The sources of chlorides in water are mainly road salts, wastewater, storm sewers and animal feed, etc., [39]. Surface water bodies often have a low concentration of chloride and are home to main physiological processes. High chloride concentration demolition metallic pipes and structures, as well as it harm growing plants. Chloride content in water samples would be determined by the Argentometric Method.

2.7.8 Calcium (Ca)

Calcium is the greatest significant and abundant in the human body and sufficient consumption is essential for normal growth and health. Around 95% of the calcium in the human body is stockpiled in bones and teeth. The high deficiency of calcium in humans may cause; rickets, poor blood clotting, bones fracture, etc. The maximum daily requirement is of the order of 1-2 grams and comes from most dairy products. There is certainly evidence indicating that the incidence of heart disease is reduced in areas served by a public water supply with a high degree of hardness, the primary constituent of which is calcium so that the presence of the element in a drinking water supply is advantageous to health [40].

2.7.9 Magnesium (Mg)

Magnesium is plentiful and a major nutritional requirement for humans (0.3–0.5 g/day). It is the second major component of hardness and it generally comprises 15–20% of the total hardness expressed as $CaCO_3$ [40]. The human body contains about 25 g of magnesium (60% in bones and 40% in muscles and tissues).

2.7.10 Copper (Cu)

Copper is a metal and an essential trace mineral for all known living organisms including humans. Copper and its compounds are common in the environment in rocks, soil, and air. It is also commonly found at low levels in natural water bodies. Humans widely use copper, for instance, it is applied in industries and agriculture. The production of copper is lifted nowadays. Due to this, its versatility and quantities in the environment have increased. The world's copper production is still rising. This means that more and more copper ends up in the environment. Copper enters the environment through natural sources and human activities [73–76]. Thus, it can enter water sources from natural processes (e.g. soil weathering), human activities (e.g., agricultural runoffs), or from the corrosion of conduits (pipes fittings) in the water distribution system [77, 78]. Copper is present in tap water principally as a result of dissolution or leaching (i.e. corrosion) from components of distribution and plumbing systems that contain copper (pipes, fittings, and brass faucets). Characteristics of the water that can increase the leaching of copper include low pH, high temperature, and reduced hardness [78]. The length of time that the water stays in pipes can also greatly increase the concentration of copper in drinking water [79].Copper is an essential element for all known living organisms including humans and animals at required levels of intake. For instance, copper is a major component of the oxygen-carrying part of blood cells [80]. Copper, along with vitamin C, is also important for keeping blood vessels and skin elastic and flexible. In addition, it also helps the body produce chemicals that regulate blood pressure, pulse, and healing [80]. However, an excess amount of copper in drinking water may cause stomach and intestinal distress such as such as nausea, vomiting, diarrhea, and stomach cramps.

2.7.11 Zinc (Zn)

Some zinc is released into the environment by natural processes, but most comes from activities of people like mining, steel production, coal burning, and burning of waste. It attaches to the soil, sediments, and dust particles in the air. Rain and snow remove zinc dust particles from the air. Zinc compounds can move into the groundwater and lakes, streams, and rivers. Most of the zinc in soil stays bound to soil particles [81, 82].

2.7.12 Iron (Fe)

Iron occurs widely in nature and is found in many natural and treated waters. It is an objectionable constituent in both domestic and industrial water supplies. The presence of iron affects the taste of beverages and causes unsightly staining of laundered clothes, plumbing fittings, swimming pool surfaces, and the like. The formation of insoluble ion deposits is troublesome in many industrial applications and agricultural water uses such as drip feed irrigation. In industry, iron salts occur through corrosion of plants and equipment, and from industrial processes [83]. Iron is, therefore, an important test for the monitoring of natural and drinking waters, corrosion control in industry, and the checking of effluents and wastewaters [84].

2.7.13 Manganese (Mn)

Manganese is a very abundant element, widely distributed in the earth's crust. It does not occur naturally in the native state, the most important manganese-containing minerals being oxides, silicates, and carbonates, while the most common is pyrolusite (MnO_2). Manganese is used mostly in metallurgical processes, but it is also used in the manufacturing of dry-cell batteries, glass, fertilizers, and in the leather and textile industries. Manganese compounds are used in the manufacturing of products such as batteries, steel, and unleaded petrol. Manganese dioxide is commonly used in the production of dry-cell batteries, matches, fireworks, porcelain, and glass-bonding materials. Manganese chloride is a precursor of other manganese compounds. It is used as a catalyst in the chlorination of organic compounds. Manganese Sulphate is used as a fertilizer, livestock nutritional supplement, and ceramics.

Manganese is an important electrolytic constituent of the blood, present in the blood plasma and body fluids, interstitial and cell fluids. Its daily dietary requirement increases from infants to adults and from males to females, with the highest daily requirements for pregnant and lactating women [85]. Manganese is essential to human health, acting as a co-factor in the active centers of various enzymes, and is required for normal development, maintenance of nerve and immune cell functions, and regulation of blood sugar and vitamins, among other functions. Overexposure to this metal, however, can be toxic to many organ Systems and across different life stages [85].

2.7.14 Nickel (Ni)

Nickel is one of the essential heavy metals present in the earth's crust. It is found in sandstone and slate, mainly present as pentlandite, an element that accumulates in sediments of biological cycles. It enters the water from power plants, waste incinerators, and metal industries. It also enters through improper diffusion of nickel-cadmium batteries Nickel compounds may also be found in sludge, and slags and fly ashes from waste incinerators. Nickel is a dietary element required for many organisms, but an increased concentration of nickel in groundwater [86] leads to many hazardous effects like teratogenic and carcinogenic to mammals.

2.7.15 Cobalt (Co)

Cobalt is of trace metal that is essential for living organisms. It is founded in low concentrations [87, 88] in the earth's crust and natural waters. Microorganisms need this element for metabolism and growth but it causes digestion failure as much as other heavy metals when the concentration of this element exceeds a certain level. This element is required for carboxypeptidase [89], synthesis of vitamin B_{12} [90], and formation of methyl coalmine [91]. Another benefit of cobalt is stimulation in the production of red blood cells [92] and treating anaemia in pregnant women and help for human health. When the concentration of cobalt exceeds, it could be dangerous for human health. Toxic doses of cobalt cause bad effects such as asthma, pneumonia, vomiting, vision problems, heart problems [93], thyroid damage, shortness of breath, cough, dyspnea, decreased pulmonary function, nodular fibrosis, permanent disability, and final death. Also, weight loss, dermatitis, and respiratory hyper sensitivity are other effects of this element [94].

2.7.16 Chromium (Cr)

Chromium is one of the heavy metals present in nature but it occurs only in a combined state. It exists as trivalent and hexavalent states. A trace amount of Chromium compound is present in water. It is discharged into groundwater or surface water through metal refinery industries and alloy industries. Hexavalent chromium enters the water from industrial wastewater which is mainly discharged from paints and tanning. Trivalent chromium is an essential trace element for humans. It plays important role in the removal of glucose from blood with help of insulin. However, chromium trioxide dust in the workplace may cause cancer and damages the respirational system. Meanwhile, hexavalent chromium [95] is highly toxic. It causes an allergic and asthmatic reaction. It is more carcinogenic than trivalent chromium.

2.7.17 Cadmium (Cd)

Cadmium is the one most commonly found metal. It is found with zinc, carbonate, and sulphide ore. It is also found as a by-product in the refining of other metals. It enters into groundwater from different sources one source is ingestion of grown foodstuffs, especially grain and leafy vegetables, which readily absorb cadmium from the soil. The cadmium may occur in groundwater naturally or as a contaminant from sewage sludge, fertilizers, polluted groundwater, or mining and industrial effluents [96]. An increase of cadmium may change the pH of the water. Cadmium can be present in groundwater from a wide variety of sources in the environment and industry.

2.7.18 Lead (Pb)

Lead is toxic and a major hazard to humans and animals. Lead has two quite distinct toxic effects on human beings, physiological and neurological. The relatively immediate effects of acute lead poisoning are ill-defined symptoms, which include nausea, vomiting, abdominal pains, anorexia, constipation, insomnia, anemia, irritability, mood disturbances, and coordination loss. In more severe situations, neurological effects such as restlessness, hyperactivity, confusion, and impairment of memory as well as coma and death can result from lead poisoning [97]. Lead does not undergo degradation or decomposition. Thus it is long persistent in the environment and exacerbates its threat to human health. Lead is used in many industries, including lead smelting and processing, battery manufacturing, pigments, solder, plastics, cable sheathing, fuels, ammonification, and ceramics. Due to urbanization, lead and other metals are regularly discharged into fields, water, and soils through sewage slugs, urban runoff, and automobile exhaust [98]. Lead was most investigated in the context of its public health effects next to As. Lead can affect the arterioles and capillaries resulting in cerebral edema and neuronal degradation.

Another system affected by lead is the reproductive system. The exposure can cause reproductive toxicity, miscarriages, and degenerated offspring [99, 100]. Although significant fractions of lead could be attributed to drinking water other sources such as lead paint, dust, and leaded gas could be the important sources of lead [101].

2.8 Water Quality Standards

Water quality requirements vary according to the proposed use of water such as drinking, irrigation, fishing and wild propagation, industrial, recreational, and power generation. Standards for drinking water have evolved over the years as knowledge of the nature and the effects of various contaminants have grown. Water quality standards are set by governmental agencies and represent a statutory requirement. Generally, it is stated that drinking water should be free of suspended solids and turbidity that is it has to be tasteless and odorless, that dissolved inorganic toxic substances and pathogens should be absent. The permissible limits of domestic water supply for drinking have been laid by national and international organizations. For example, the Compulsory Ethiopian Standard for Drinking Water Specification (CES-58) [102] outlines the physical, chemical, and bacteriological requirements of water for drinking and domestic purposes. Likewise, WHO [53], EU [103], US-EPA [104], and Health Canada [105] have proposed quality requirements for drinking water. The physical characteristics of drinking water must conform to the levels specified in Table 2.1a.There are certain chemical substances that, if they are present above certain levels of concentration in supplies of drinking water, are likely to give rise to actual danger to health. A list of such substances, of the levels of concentration which they should not be allowed to exceed in piped supplies, is given in Table 2.1b. The presence of any of these substances above the concentrations quoted should constitute grounds for the rejection of the water from use as a piped supply.

Table 2.1a: Physical Characteristics of Drinking Water

Characteristics	**CES-58 [102]**	**WHO[53]**	**EU[103]**	**US-EPA [104]**	**Health Canada[105]**
Odor	Unobjectionable	Unobjectionable	Acceptable to consumers	--	Inoffensive
Taste	Unobjectionable	Unobjectionable	Acceptable to consumers	--	Inoffensive
Turbidity, NTU	5	< 1.5 NTU	Acceptable to consumers	--	< 1.0 NTU
Color, TCU	15	< 5	Acceptable to consumers	15	≤ 15

Table 2.1b: Maximum permissible level in mg/L of toxic and/or disease-causing substances in drinking water

Substance or characteristic	CES-58 [102]	WHO[53]	EU[103]	US-EPA [104]	Health Canada[105]
Cadmium	0.003	0.003	0.005	0.005	0.005
Lead	0.01	0.01	0.01		0.005
Chromium	0.05	0.05	0.05	0.1	0.05
Arsenic	0.01	0.01	0.01	0.01	0.01
Selenium	0.01	0.01	0.01	0.05	0.05
Cyanide	0.07	0.07	0.05	0.2	0.2

Table 2.1c: describes the chemical requirements that affect the palatability properties of drinking water. These are chemical substances that may be found in piped supplies of drinking water, although they do not constitute a hazard to the health of people drinking the water, may nevertheless give rise to the trouble of one sort or another if they are present in excessive amounts. A list of such substances is given in table 2.1c; together with the approximate level above which trouble is likely to arise.

Table 2.1c: Maximum permissible level in mg/L of characteristics that affect the palatability of drinking water.

Substance or characteristic	CES-58 [102]	WHO[53]	EU[103]	US-EPA [104]	Health Canada[105]
Total hardness (as $CaCO_3$)	300	--	--	--	--
Total dissolved solids	1,000	--	--	500	≤ 500
Total iron	0.3	0.3	0.2	0.3	≤ 0.3
Manganese	0.5	0.4	0.05	0.05	≤ 0.02
Magnesium	50	--	--	--	--
Calcium	75	--	--	--	--
Copper	2	2	2	1.0	1.0
Zinc	5	3	--	5	≤ 5.0
Nickel	--	0.07	0.02		--

Sulfate	250	--	250	250	≤ 500
Chloride	250	250	250	250	≤ 250
Nitrate	50	50	50	--	--
Fluoride	1.5	1.5	1.5	2.0	1.5
Total Alkalinity ($CaCO_3$)	200	--	--	--	--
Sodium	200		200		≤ 200
Potassium	1.5	--	--	--	--
pH value, units	6.5 to 8.5	8.2 – 8.8		6.5 - 8.5	7.0–10.5

Table 2.1d describes the bacteriological requirements of treated drinking water. The drinking water must not exceed the levels shown in Table 2.1d.

Table 2.1d: Bacteriological levels

Organism	CES-58 [102]	WHO[53]	EU[103]	US-EPA [104]	Health Canada[105]
Totalviable organisms, colonies per Ml	Must not be detectable	Absent	0	0	None detectable
Fecal streptococci per 100 Ml	Must not be detectable		0	0	None detectable
Coliform organisms number per 100 Ml	Must not be detectable		0	0	None detectable
***E. coli* number per 100 mL**	Must not be detectable		0	0	None detectable

3 MATERIALS AND METHODS

3.1 Study Duration

Sample preparation and analysis were carried out at Hawassa University research laboratory between June 2024 and August 2024.

3.2 Description of the Study Area

The study was conducted in the Oromia Regional State of Ethiopia, Guji Zone, Ana Sora district (Figure 3.1).Guji Zone is one of the 21 Zones of Oromia Regional State. It is found in Southern part of the Oromia Regional State. The capital town of the Zone is Nagelle, which is 604 km far away from Addis Ababa, the capital city of Ethiopia. Guji Zone is bounded by Southern Nation, Nationality and Peoples Regional State in North, Somali Regional States in South, Borena Zone in West and Bale Zone in East. Guji Zone is located between 38°– 40° East longitude and latitude 4° – 5° on the North, and the altitude ranges from 500m up to 3500m above sea level.

The area of the Zone is estimated to cover about 18,557.05 km^2 or 3,545,400 hectare. Of which, around 1,392,048.05 hectare is arable land, while 702,080 and 1,167,145 hectare of its land is grazing and forest land, respectively[106].The Zone accommodates three types of climate conditions- Dega, WoinaDega and Kolla and accounts 13%, 19% and 68%, respectively. The zone has bi-modal rain seasons namely the summer (June to November) and spring (March to May). In the De

ga areas, the rain ranges from 1000mm-1500mm, Woina Degas 750mm–1000mm and Kola areas 500mm-750mm get annually [106]. Demographically, the estimated total population of the zone is 1,638,022 of which 823,564 are male and 811,140 are female [107]. From the total population, 1,441,598 (88%) lives in rural area of the zone. Although, there are diverse ethnic groups live in Guji zone, the Guji Oromo is numerically the dominant one [107] and their major livelihood is pastoralism and farming.

Currently,GujiZone has thirteen districts and two urban administrations. This study was confined to the newly established districts in (2006), known by the name Ana Sora as the society appeared to use groundwater sources extensively for various purposes. Thus, the study was conducted in three kebeles of Ana Sora districts namely BubeKorsa, HiyoKomele and Irba Buliyo. Three ground water points were selected randomly from BubeKorsa and HiyoKomele respectively. However, as there is only one ground water point in Irba Buliyokebele, three groundwater samples were taken at different times.

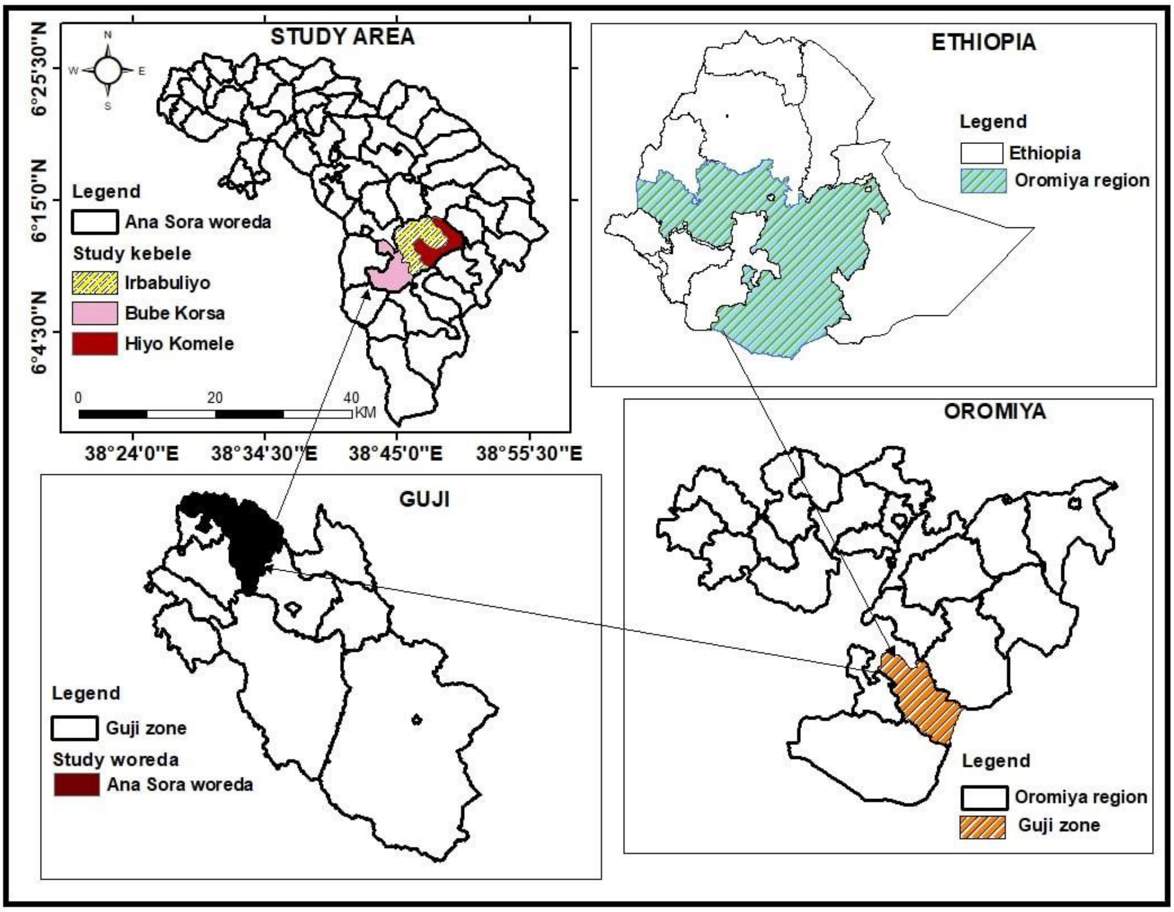

Figure 3.1: Map of the study area

3.3 Sampling and Sample Collection

Ground water samples were taken from three kebeles of Ana Sora district namely BubeKorsa, Hiyo Komele, and Irba Buliyo at the point of collection to test the quality of the water being consumed by the community. Therefore, a total of three composite ground water samples were collected purposefully for analysis. All water samples were collected in a clean 2.0 Land 1.0 L plastic bottles and transported to Hawassa University research laboratory. Then, all samples were immediately acidified by adding 2.0 mL of concentrated HNO_3 (69–72%) after parameter

rs such as temperature, pH, and conductivity have been measured, and then kept in the refrigerator at a low temperature of about 4˚C before chemical analyses.

3.4 Apparatus and Instrument

Different Instruments and apparatuses have been used to analyse the concentration of heavy metals in the water samples. Round bottom flasks (250mL) for the digestion of water samples; Borosilicate volumetric flasks (50mL and 100mL sizes) were used for the dilution of samples and preparation of metal standard solutions. Measuring cylinders (DURAN, Germany), pipettes (PYREX, USA), microliter pipettes (20-50 µL and 100-1000 µL size, DRAGON MED, Shangai, China) were employed for measuring different quantities of volumes of sample solution, acid reagents, and metal standard solutions. Whatman filter paper No.42 was used to filter digested water samples. Concentrations of metals were determined by a flame atomic absorption spectrophotometer (BUCK SCIENTIFIC, Model 210VGP AAS, USA) equipped with a deuterium background corrector and hollow cathode lamps with a flame produced from air-acetylene as oxidant-fuel or flame atomizer. AD800pH/mV/EC/TDS meter (Adwa Instruments, Hungary) was used to measure temperature, pH, EC, and TDS.

3.5 Chemicals and Reagents

All reagents and chemicals used in this study were analytical grades. Nitric acid, 69-72% HNO_3 (Riedel-de Haen) was used in the sample digestion steps. Stock standard solutions of concentration 1000 mg/L of the metals Ca, Mg, Cu, Mn, Co, Cr, Ni, and Pb(BUCK SCIENTIFIC, PURO-GRAPHIC) as nitrate salt standard solutions were used to prepare intermediate standard solutions. HCl (37%), and Phenolphthalein were used for the determination of total alkalinity; $AgNO_3$, NaCl, and K_2CrO_4 were used for the determination of chloride content of the water sample; Ethylene diaminetetraacetic acetic acid (EDTA), Eriochrome black T (EBT), MgSO4, NH_3/NH_4Cl buffer for the determination of the hardness of the water sample. Distilled water was used for all dilutions. Distilled water was used to dilute the sample and intermediate metal standard solutions and to rinse glassware and sample bottles.

3.6 Determinations of temperature, pH, electrical conductivity, and Total Dissolved Solids (TDS)

Temperature, pH, electrical conductivity, and TDS were measured using an AD8000 pH/mV/EC/TDS/Temp meter.

3.7 Digestion of Water Samples

Nitric acid digestion techniques were used as they are adequate for clean samples such as drinking water to reduce interference by organic matter and to convert metals associated with particulates to a form (usually the free metal) that can be determined by atomic absorption spectrometry.

In this method, 100mL of well-mixed, acid-preserved drinking water samples were transferred to a flask. In a hood, 2mL concentrated HNO_3 (69–72%) was added. Then, the flask was covered with a ribbed watch glass to minimize contamination. The content of the flask was subjected to a slow boil and evaporated on a hot plate to the lowest volume possible (about 10mL to 20mL) before the sample dries. The flask was removed from the hotplate (Spectrum Hot Plate) and the wall and the watch glass cover was washed down with distilled water into the flask and then filtered to a 100mL volumetric flask. Then, the contents of the flask were cooled, diluted to mark, and mixed thoroughly. The portion of the solution was used for required total metal determinations. All samples were digested during the same procedure. Furthermore, a reagent blank was prepared with the same acids and subjected to the same digestion procedure as the sample to correct for impurities present in acids and reagent water.

3.8 Determination of Total Alkalinity

Alkalinity is a useful measure of the capacity of water to resist acidification from acid precipitation. The presence of carbonate, bicarbonate, and hydroxide ions impart the alkalinity of natural or treated waters. In this method, 100mL of water sample would be pipetted into a 250mL conical flask and 3 drops of methyl orange indicator would be added to the sample. Then, the sample solution would be titrated with 0.10N HCl solutions from the burette until the indicator color changes from yellow to red. The volume of acid used corresponds to the sum of carbonate and bicarbonates present in an aqueous solution. The titration would be carried out in triplicate. If the volume of titrant used was recorded as V_2 (mL), then the total alkalinity is calculated [108, 109] as:

$$\text{Total Alkalinity}\left(\frac{\text{mg}}{\text{L}}\text{CaCO}_3\right)=\frac{V_2\times\text{Normality of HCl}\times 50\times 1000}{\text{Volume of the sample (mL)}}$$

3.9 Determination of Total Hardness (TH)

In this study, hardness is measured by titration of a water sample against standard EDTA at pH 10 and using an indicator (EBT) solution to signal the endpoint. In this method, 100 mL of each of the water samples would be pipetted out in a washed 250 mL Erlenmeyer flask. Then, 10 mL of ammonia/ammonium chloride buffer solution and 3 drops of EBT indicator solution would be added into the flask, which turns the color of the solution wine red. This solution would be titrated against previously standardized 0.01 M EDTA solution taken in the burette until the color changes from wine red to faint violet to pure blue or sky blue which indicated the endpoint. The final reading of the burette is noted and the titration is repeated to get a concordant value. Then, the total hardness (concentration of calcium and magnesium ions) is expressed in mg/L $CaCO_3$ and it is calculated as [110]

$$\text{Total Hardness} = \frac{\text{Molar mass of CaC O}_3 \times 1000 \times M_{EDTA} \times V_{EDTA\ used\ in\ the\ titration}}{\text{Volume of water sample (mL)}used}$$

3.10 Determination of Chloride

Chloride In this method, Silver nitrate (0.0141 M) was prepared by dissolving 2.4 g of powdered $AgNO_3$with distilled water, and then it was made up to the mark in a 1000 mL volumetric flask. The silver nitrate solution was transferred into a well-rinsed 50 mL burette. Then, 50 mL of each water sample was measured using a measuring cylinder and 1.0 mL of potassium chromate indicator will be measured with a dropper and added to the sample. In the conical flask, the mixture was titrated with the silver nitrate solution from the burette to a reddish-brown precipitate that signals the endpoint. Titration as done thrice and the average volume of $AgNO_3$will be recorded. A blank value was established by titration with 50 mL of distilled water. Calculation of the concentration of chloride ions is done using the following formula [111]:

$$\text{Chloride} \left(\frac{\text{mg}}{\text{L}}\right) = \frac{(\text{A} - \text{B}) \times \text{Normalityof AgNO}_3 \times 35.450}{\text{Volume of sample (mL)}}$$

Where A: volume of titrant used for the water sample; B: volume of the titrant used for the blank (distilled water)

3.11 Determination of Ca, Mg, Cu, Mn, Co, Cr, Ni, and Pb

The determination of metals (Ca, Mg, Cu, Mn, Co, Cr, Ni, and Pb) would be carried out using Flame Atomic Absorption Spectrometer (Buck Scientific Model 210 AA,Buck Scientific, Inc.) after a standard curve was prepared for each elements using working standard solutions of each element to be analysed. Four working standard solutions of each metal would be prepared from certified stock standard solution (1000 mg/L) of each element. Then, the working standard solutions for each element would be aspirated and absorbance would be recorded. Then, the absorbance values would be plotted as a function of the concentration of working standards to generate a calibration curve. Once the calibration curve is linear and satisfied, the sample solution would be aspirated and their concentration is read directly from the Flame AAS.

3.12 Instrument Operating conditions and Calibration

3.12.1 Instrument Operating Condition of FAAS

The determination of elements such as Ca, Mg, Cu, Mn, Ni, Co, Cr, and Pb were carried out after instrument parameters such as lamp alignment, slit width, and wavelength were adjusted and their respective hollow cathode lamp was inserted into the turret of the atomic absorption spectrophotometer and the solution was successively aspirated into the flame. Three replicate determinations were carried out for each sample. The operating conditions of the instrument employed for each analyte are shown in Table 3.1.

Table 3.1: Instrumental operating conditions for each element analyzed

Elements	Ca	Mg	Cu	Mn	Co	Cr	Ni	Pb
Wavelength, nm	422.7	285.2	324.7	279.5	240.7	357.9	239.7	283.2
Slit width, nm	0.7	0.7	0.7	0.7	0.2	0.7	0.2	0.7

3.12.2 FAAS Calibration

Atomic absorption spectrophotometer calibration for each metal analysis was carried out by preparing four concentrations of working standard solutions from Stock standard solutions (1,000 ppm) of each element. The four concentrations of working standard solutions used for each metal are shown in Table 3.2.

Table 3.2: Concentrations of working standards for each metal analysed using FAAS

Ca	Mg	Cu	Mn
0.5; 1.0; 2.0; 4.0	0.05; 2.0; 4.0; 6.0	0.008; 0.5; 1.5; 2.0	0.05; 0.1; 0.5; 1.0
Ni	**Co**	**Cr**	**Pb**
0.06; 0.1; 0.5; 1.0	0.06; 0.5; 1.0; 2.0	0.05; 0.5; 1.0; 2.0	0.09; 0.1, 0.5; 1.0

3.13 Method validation

Method validation is the process of providing that the analytical method is acceptable for its intended purpose appropriate quality assurance procedures and precautions were carried out to ensure the reliability of the results. Distilled water and analytical grade reagents were used throughout the study. Reagent blank determinations were used to correct the instrument readings. For validation of the analytical procedure, a recovery study was carried out by spiking and homogenizing several already analysed samples with specific amounts of standard solutions of the metals.

3.13.1 Method Detection Limit (MDL)

Blank samples were prepared for each sample using a similar procedure for sample digestion. The method detection limits for each metal were estimated by digesting six analytical blanks for each water sample. Each blank solution was run with FAAS for the level of the metal in a similar manner as the samples and triplicate readings were recorded. Then, the standard deviations of the blanks' concentration were calculated and used to calculate the method detection limit as follows [113],

$$\text{MDL} = 3 \times \text{Standard deviation of the blank}$$

3.13.2 Method Validation (Recovery Experiment)

The accuracy of the analytical procedure for sample analysis was tested by spiking experiment as there were no available certified reference materials and calculating the %recovery [113]. In this experiment, one sample was selected, spiked with 50 µLof 1000 mg/L of Ca, Mg, and Cu standard solutions at once that contained 100 mL of the water sample and then digested in triplicate following the digestion procedure used for water samples digestion. The digested spiked samples were analysed for their respective metal content using FAAS. Thus, the concentrations for the "spiked" and "unspiked" samples were used to calculate the %recovery as follows [113]:

$$\%Recovery = \frac{Amount\ recovered}{Spiked\ amount} \times 100$$

$$= \frac{(Conc. spiked\ sample\ -\ Conc. unspiked\ sample)}{Spiked\ amount} \times 100$$

3.14 Statistical Analysis

The data analysis for all parameters was done by using SPSS version 16.0and the Microsoft Excel program. The mean, standard deviation, range, and one-way analysis of variance (ANOVA) were done using the above statistical analysis tools. A 95% significance level was used for all statistical calculations.

4 RESULTS AND DISCUSSION

4.1 Results of the physicochemical analysis

The results (minimum, maximum, and average**)** of the physicochemical composition of drinking ground water samples were presented in Table 4.1a and b.

Table 4.1a: Physicochemical composition of drinking water collected from selected Kebeles of Ana Sora district,Guji zone

Sample location	**Temperature (°C)**	**pH**	**Electrical conductivity (μS/cm)**
	Mean ± SD	Mean ± SD	Mean ± SD
BubeKorsa	22.5± 0. 4	6.6± 0.1	3.7 ± 0.1
HiyoKomele	23.1± 0.3	7.1 ± 0.1	23.7 ± 0.5
Irba Buliyo	20.8± 0.8	6.9 ± 0.1	4.8 ± 0.1

Table 4.1b: composition of drinking water collected from selected Kebeles of Ana Sora district, Guji zone

Sample location	**TDS (mg/L)**	**Total hardness (mg/L $CaCO_3$)**	**Total alkalinity (mg/L $CaCO_3$)**	**Chloride (mg/L)**
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
BubeKorsa	12.8 ± 0.2	42.4 ± 2.1	25.0 ± 5.0	2.5 ± 0.5
HiyoKomele	24.5 ± 0.4	14.7 ± 1.5	38.3 ± 7.6	3.8 ± 0.7
Irba Buliyo	8.5 ± 0.1	33.0 ± 2.0	23.3 ± 2.9	2.3 ± 0.3

Temperature

Temperature refers to degree of hotness or coldness and it can be measured in degree Celsius. Drinking water temperature value of the three sampling locations such as BubeKorsa, HiyoKomele, and Irba Buliyo were ranged from 22.0–22.8, 22.9 –23.5, and 20.0–21.5 °C at the point of distribution to the consumer respectively. The drinking water temperature range for the three water samples were below the drinking water temperature reported in the city of Cali (Colombia) resulted in temperatures between 25 ◦C and 28 °C [114]. The results of a one-Way ANOVA analysis indicated that the temperature value of the drinking water samples were statistically significantly different, $F (2, 6) = 14.490$, $P = 0.005$, among the three drinking water samples(appendix I).However, Post hoc test revealed the temperature value of BubeKorsa and HiyoKomele water sample were not statistically significantly different.

pH

pH is a term used universally to express the intensity of the acid or alkaline condition of a solution. The pH for drinking water generally lies between 6.5 and 8.5 at 25°C [102]. However, high pH causes a bitter taste, water pipes and water-using appliances become coated with deposits and it depresses the effectiveness of the disinfection of chlorine, thereby causing the need for additional chlorine when pH is high. Low pH water will corrode or dissolve metals and other substances [115].In the present study, the pH value of drinking water samples taken from BubeKorsa, Hiyo Komele, and Irba Buliyo were ranged from 6.49 – 6.75, 6.97 –7.18, and 6.70– 6.98 respectively. These pH values were within the acceptable pH range specified in Ethiopian Standards [102].The results of a one-Way ANOVA analysis showed that the pH values were statistically significantly different, $F (2, 6) = 10.147$, $P = 0.012$, among the three drinking water samples (appendix I).However, Post hoc test revealed the pH value of BubeKorsa and Irba Buliyo water sample were not statistically significantly different. Similarly, the pH value of Irba Buliyo and HiyoKomele water sample were not statistically significantly different.

Electrical conductivity

Electrical conductivity is a measure of the ability of water to conduct an electrical current and it depends on the total amount of dissolved salts present in a water sample. In the present study, the electrical conductivity value of drinking water samples taken from BubeKorsa, HiyoKomele, and Irba Buliyo were ranged from 3.64–3.76, 2.32–2.40, and 4.70–4.87 µS/cm respectively. These values were below the maximum permissible limit of electrical conductivity in drinking water, prescribed as 1500 µS/cm and 2000 µS/cm[24, 102]. The water samples from the three sampling locations were categorized as excellent, because the measured electrical conductivity values for all water samples fall in the range 0–333 µS/cm [116]. Moreover, the observed electrical conductivity value in all the three type of drinking water samples were the lowest as compared to previous study by Meseret [117] (496 µS/cm), AlemnewBerhanuKassegne&SeyoumLeta [118] (63.96 µS/cm to 300.37 µS/cm), and Gebreyesus [119] (3700 µS/cm).The results of a one-Way ANOVA analysis showed that there was significant difference among the three drinking water samples on the values of electrical conductivity (µS/cm), $F (2, 6) = 4849.332$, $P < 0.001$(appendix I).

TDS

TDS is the overall measure of the inorganic salts (calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates) dissolved in the groundwater. The total dissolved solids for water samples taken from BubeKorsa, HiyoKomele, and Irba Buliyo were ranged from 12.67–12.98, 24.05–24.85, and 8.42–8.65 mg/L respectively with maximum value recorded in HiyoKomele and minimum value recorded in Irba Buliyo. According to the WHO standards and Ethiopian drinking water guidelines [24, 102], the highest desirable and highest permissible level for total dissolved solids is 500 mg/L and 1000 mg/L, respectively. Therefore, TDS values for all the studied drinking groundwater samples were below WHO standards and Ethiopian drinking water guidelines and they are classified as fresh and excellent (< 300 mg/L) water [120].Moreover, the observed total dissolved solids value in all the three type of drinking water samples were the lowest as compared to previous study by AlemnewBerhanuKassegne&SeyoumLeta[118] (58.17 to 269.4 mg/L).The results of a one-Way ANOVA analysis showed that there was significant difference among the three drinking water samples on the values of total dissolved solids (mg/L), $F (2, 6) = 2998.903$, $P < 0.001$(appendix I).

Total hardness

Hardness is simply the resistance of water in forming lather with soap. It is caused by dissolved metallic ions, predominantly calcium and magnesium cations. Hardness is most commonly expressed as milligrams per litter of calcium carbonate. The total hardness for water samples taken from BubeKorsa, HiyoKomele, and Irba Buliyo were ranged from 40.04–44.04, 13.01–16.01, and 31.03–35.03 mg/L $CaCO_3$ respectively with maximum value recorded in BubeKorsa and minimum value recorded in HiyoKomele. The values of total hardness for all of the drinking groundwater samples lied far below the maximum permissible limit specified in WHO standards and Ethiopian drinking water guidelines [24, 102].According to the classification of water based on total hardness value [121], all the studied drinking groundwater samples were belonged to soft water.

The observed total hardness value in HiyoKomele and Irba Buliyo drinking water samples were below reported value of total hardness in previous study by AlemnewBerhanuKassegne&SeyoumLeta [118] (40 to 215 mg/L $CaCO_3$).However, hard water is not a serious health concern, but it may affect the acceptability of drinking water [64]. The results of a one-Way ANOVA analysis showed that there was significant difference among the three drinking water samples on the values of total hardness, $F (2, 6) = 167.156$, $P < 0.001$(appendix I).

Total alkalinity

The total alkalinity is typically defined as a measure of the capacity of water to neutralize a strong acid. It is a measure of the presence of bicarbonate, carbonate or hydroxide constituents. In this study, the total alkalinity for water samples taken from Bube Korsa, HiyoKomele, and Irba Buliyo were ranged from 20.0–30.0, 30.0–45.0, and 20.0–25.0mg/L $CaCO_3$ respectively with maximum value recorded in HiyoKomele and minimum value recorded in Irba Buliyo. The values of total alkalinity for all of the drinking groundwater samples lied far below the maximum permissible limit specified in Ethiopian drinking water guidelines [102]. There is no health concerns related to alkalinity. However, water with low levels of alkalinity (less than 150 mg/L) is more likely to be corrosive. High alkalinity water (greater than 150 mg/L) may contribute to scaling. The results of a one-Way ANOVA analysis showed that there was significant difference among the three drinking water samples on the values of total hardness, $F (2, 6) = 6.636$, $P = 0.03$(appendix I). However, Post hoc test revealed the total alkalinity value of BubeKorsa and Irbab Buliyo water sample were not statistically significantly different. Similarly, the total alkalinity value of BubeKorsa and HiyoKomele water sample were statistically the similar.

Chloride

The concentration of chloride for water samples taken from BubeKorsa, HiyoKomele, and Irba Buliyo were ranged from 1.98–2.98, 2.978–4.47, and 1.98–2.48 mg/L respectively. These values were very much below the maximum limit specified in Ethiopian drinking water guidelines [102]. However, there is no health standard. Chloride levels less than 10 mg/L are desirable, while chloride levels more than 250 mg/L may cause a salty taste. The results of a one-way ANOVA analysis indicated that there was significant difference among the three drinking water samples on the values of chloride, $F (2, 6) = 6.636$, $P = 0.03$(appendix I).However, Post hoc test revealed the chloride value of Irba Buliyo and BubeKorsa water sample were not statistically significantly different. Similarly, the chloride value of BubeKorsa and HiyoKomele water sample were not statistically significantly different.

4.2 Calibration curve for metals analysed using AAS

The correlation coefficients for the calibration curves for all the selected metals analysed using FAAS were greater than or equal to 0.999 which assured the linearity of instrumental response for individual metals or these correlation coefficients showed that there was a very good correlation (linear relationship) between concentration and absorbance. The equation of the graph and its R^2 value for each metal are shown in Table 4.2. The calibration graphs for the selected metal analysed were shown in appendix II.

Table 4.2: Calibration graph equation and R^2 value

Metal	Calibration Equation	R^2 Value
Ca	Y= 0.0503x - 0.0019	0.9998
Mg	Y = 0.0016x + 0.0001	0.9995
Cu	Y = 0.0518x + 0.0013	0.9997
Mn	Y = 0.1127x - 0.0007	0.9996
Ni	Y = 0.0269x + 0.0005	0.9993
Co	Y = 0.0435x - 0.0003	0.999
Cr	Y = 0.0751x + 0.0005	0.9993

Pb	Y = 0.0276x - 0.0003	0.9998

4.3 Method detection limits values

The method detection limit values for each element analysed in drinking groundwater samples were shown in Table 4.3. These values were above the detection limit of the instrument.

Table 4.3: Method detection limit for the elements determined in groundwater samples

Element	**Ca**	**Mg**	**Cu**	**Mn**	**Ni**	**Co**	**Cr**	**Pb**
IDL mg/L	0.05	0.005	0.005	0.03	0.05	0.05	0.04	0.08
MDL mg/L	0.5	0.05	0.008	0.05	0.06	0.06	0.05	0.09

The method detection limits estimated indicated that if the concentration of the respective element is at least equal to the detection limit, it can be detected but not quantified.

4.4 Results of the concentration of Ca, Mg, Cu, Mn, Co, Cr, Ni, and Pb

The results (minimum, maximum, and average**)** of the concentration of the elements analysed for each drinking groundwater sample taken from the selected Kebeles of Ana Sora district, Guji zone are presented in Tables 4.4.Ca, Mg, and Cu were present in all drinking ground water samples while the concentration of Mn, Ni, Co, Cr, and Pb were found to be below the detection limit of the instrument.

Table 4.4: Results of the concentration of the elements (mean + SD, n = 9, mg/L) determined in drinking groundwater samples

Sample location	**Ca**	**Mg**	**Cu**
	Mean ± SD	Mean ± SD	Mean ± SD
BubeKorsa	2.32 ± 0.03	19.7 ± 0.6	0.19 ± 0.11
HiyoKomole	9.62 ± 0.52	11.9 ± 0.06	0.30 ± 0.14
IrbaBuliyo	4.6 ± 0.04	24. 6 ± 0.02	0.13 ± 0.01

Calcium

The calcium concentration in drinking groundwater samples collected from BubeKorsa, HiyoKomele, and Irba Buliyo kebele were ranged from 1.80–2.60, 5.80–16.7, and 4.10–5.30 mg/L respectively (Table 4.4).Drinking groundwater samples from HiyoKomele have the highest average calcium content with a value of 9.62 ± 0.52 mg/L, while drinking water sample from BubeKorsa has the lowest calcium content with a value of2.32 ± 0.03mg/L. However, the average calcium content in all investigated drinking groundwater samples were below the desired level recommended by Ethiopian Standards and WHO Standards [102, 122].Previous study had reported a calcium concentration of 2.19 to 46.11 mg/L for drinking water supplied to Ankober district, Amhara region [118], which is in agreement with the present study; BerihuAbadiBerhe [123] reported calcium concentration in the wet season ranged from 41 to 178 mg/L in drinking groundwater Kombolcha town area, eastern Amhara region, which is higher than the present study.

The results of one-Way ANOVA analysis showed that there was a significant difference in the calcium content, $F (2, 24) = 13.730$, $P < 0.001$, among the drinking groundwater samples obtained from the three Kebeles (appendix III). However, Post hoc test revealed that the calcium content of drinking groundwater samples from BubeKorsa, and Irba Buliyo were statistically similar.

Magnesium

The magnesium concentration in drinking groundwater samples collected from BubeKorsa, HiyoKomele, and Irba Buliyo kebele were ranged from 11.5–25.0, 11.2–12.7, and 24.3–24.9 mg/L respectively (Table 4.4).The average concentration of magnesium in the present study was ranged from11.9 to 24. 6 mg/L with the highest average magnesium content were found in Irba Buliyo drinking water sample while the lowest average magnesium content was found in HiyoKomele drinking water sample. Therefore, the average magnesium concentration in all investigated drinking groundwater samples were complied with the Ethiopian Standards and WHO Standards [102, 124].The average magnesium concentration obtained in this study were comparable with previous reported magnesium concentration, which is in the range of 4 to 25 mg/L [123] for drinking water from Kombolcha town area, eastern Amhara region, Ethiopia. One-Way ANOVA analysis showed that there was a significant difference in the magnesium content, F (2, 24) = 35.590, P < 0.001, among the drinking groundwater samples obtained from the three kebeles(appendix III).

Copper

The copper concentration in drinking groundwater samples collected from BubeKorsa, HiyoKomele, and Irba Buliyo kebele were ranged from 0.07–0.34, 0.15–0.49, and 0.12–0.14 mg/L respectively (Table 4.4). The average concentration of copper in the present study was ranged from 0.13 to 0.30 mg/L with the highest average copper content were found in Hiyo Komele drinking water sample while the lowest average copper content was found in Irba Buliyodrinking water sample. Therefore, the average copper concentration in all investigated drinking groundwater samples were in compliance with the Ethiopian Standards and WHO Standards [77, 102]. Moreover, the average copper concentration obtained in this study were comparable with previous reported copper concentration, which is in the range of 0.09 to 0.13 mg/L [125] for drinking groundwater supplied to Woreillu town, Ethiopia. The results of one-Way ANOVA analysis showed that there was a significant difference in the copper content, F (6, 56) = 6.549, P = 0.005, among the drinking groundwater samples obtained from the three kebeles(appendix III). However, Post hoc test revealed that the copper content of drinking groundwater samples from Irba Buliyo, and Bube Korsa were statistically similar.

4.5 Results of the Recovery Experiment

Recovery experiment was carried out using selected groundwater sample (Bube Korsa). The results of the %recovery experiment for the elements found in the groundwater samples were shown in Table 4.5.

Table 4.5: Recovery test results (mean ± SD, n=9, mg/L) for the analysed elements in Bube Korsa groundwater sample

Metal	Conc. of unspiked sample (mg/L)	Amount added (50 µL of 1000 mg/L = 0.5 mg/L)	Conc. Spiked sample (mg/L)	Recovery (%)
Ca	1.90 ± 0.14	0.5	2.38± 0.16	96
Mg	12.0 ± 0.71	0.5	12.55 ± 0.35	110
Cu	0.075 ± 0.01	0.5	0.62 ± 0.03	109

The %recovery values for all the analysed elements lie within the range 96.0% to 110.0%, which is in the acceptable range (80–120 %), which suggested that the experimental procedures and the method of analysis were accurate and valid.

5 CONCLUSION AND RECOMMENDATIONS

Physicochemical drinking water quality parameters such temperature, pH, Electrical conductivity, TDS, Total hardness, Total alkalinity, and chloride, and minerals such as (Ca, and Mg), trace elements (Cu, Mn, Ni, and Co) and heavy metals (Cr and Pb) were analysed to evaluate the quality of drinking groundwater samples collected from selected Kebeles of AnaSora district, Guji zone, Oromia regional state, Ethiopia. The result showed that the values of all selected physicochemical parameters were within the acceptable standard specified in Compulsory Ethiopian Drinking Water Specifications. Metals such as Ca, Mg, and Cu were found and quantified in all drinking water samples while the concentration of Mn, Ni, Co, Cr, and Pb were found to be below the detection limit of the instrument. In general, the drinking groundwater supplied to the community in the studied kebeles were considered to be fit for human consumption although the number of sample considered in the study were not sufficient to conclude conclusively. Therefore, more research regarding the seasonal variation of the physicochemical parameters should be conducted in order to further strengthen the conclusion.

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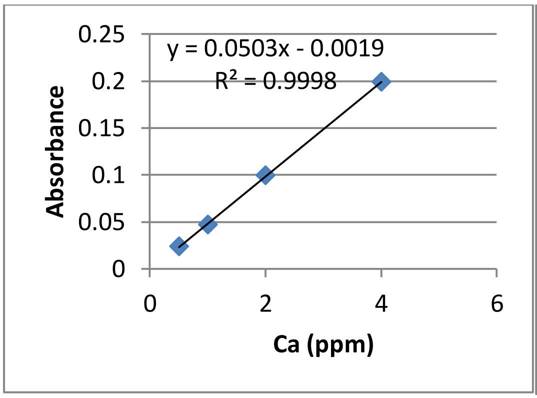
7 APPENDICES

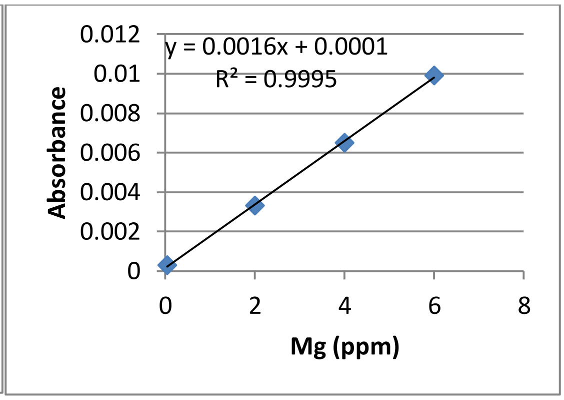
Appendex I:ANOVA analysis results for selected physicochemical parameters

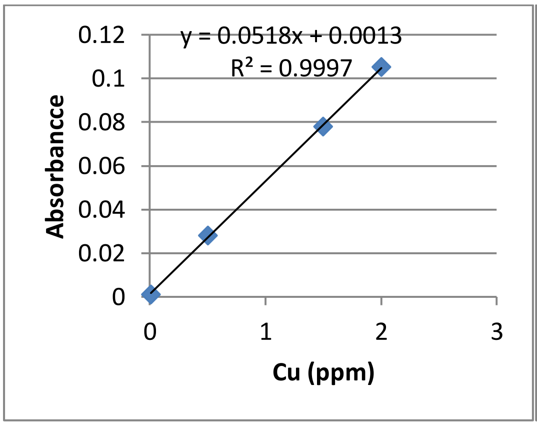
ANOVA

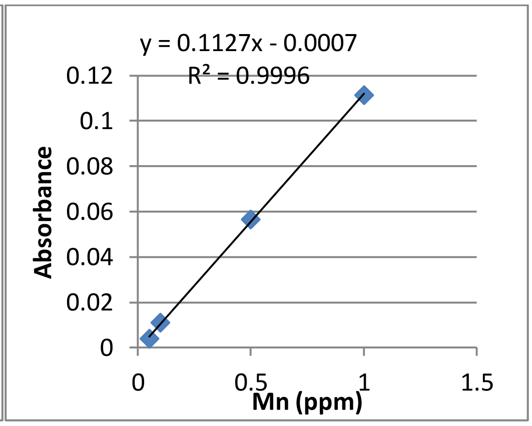
		Sum of Squares	Df	Mean Square	F	Sig.
Temperature	Between Groups	8.469	2	4.234	14.490	.005
	Within Groups	1.753	6	.292		
	Total	10.222	8			
pH	Between Groups	.363	2	.181	10.147	.012
	Within Groups	.107	6	.018		
	Total	.470	8			
Electrical conductivity (mS/cm)	Between Groups	762.315	2	381.157	4849.332	.000
	Within Groups	.472	6	.079		
	Total	762.787	8			
Total dissolved solids (mg/L)	Between Groups	409.917	2	204.958	2998.903	.000
	Within Groups	.410	6	.068		
	Total	410.327	8			
Total hardness expressed in mg/L CaCO3	Between Groups	1190.807	2	595.404	167.156	.000
	Within Groups	21.372	6	3.562		
	Total	1212.179	8			
Total alkalinity (mg/L CaCO3)	Between Groups	405.556	2	202.778	6.636	.030
	Within Groups	183.333	6	30.556		
	Total	588.889	8			
Chloride	Between Groups	3.996	2	1.998	6.636	.030
	Within Groups	1.806	6	.301		
	Total	5.802	8			

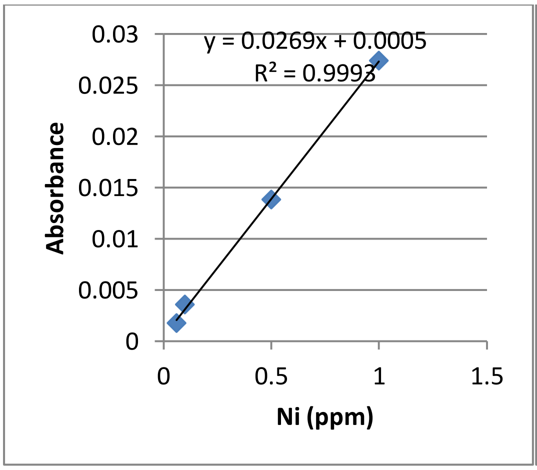
Appendix II:Calibration graphs

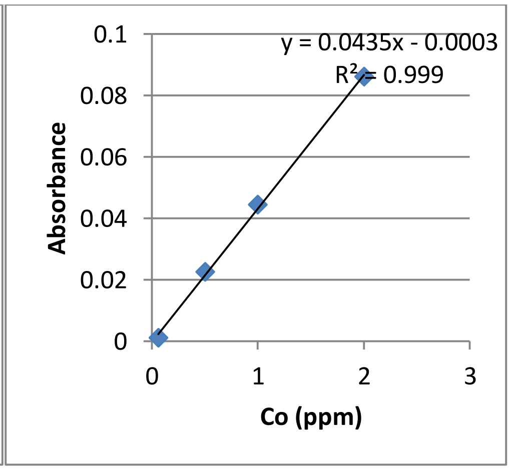


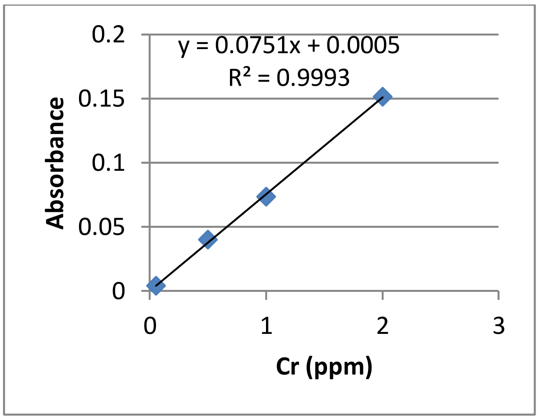


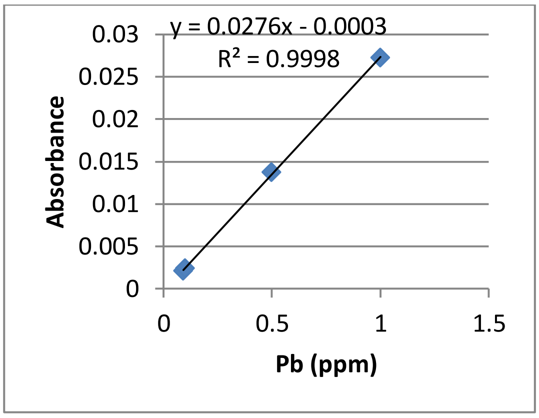









y = 0.0751x + 0.0005
R² = 0.9993
Absorbance
Cr (ppm)


y = 0.0276x - 0.0003
R² = 0.9998
Absorbance
Pb (ppm)

Appendix III:ANOVA analysis results for selected metals

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Calcium (mg/L)	Between Groups	2.511	2	1.256	13.730	.000
	Within Groups	2.195	24	.091		
	Total	4.706	26			
Magnesium (mg/L))	Between Groups	7.334	2	3.667	35.590	.000
	Within Groups	2.473	24	.103		
	Total	9.807	26			
Copper (mg/L)	Between Groups	.138	2	.069	6.549	.005
	Within Groups	.252	24	.011		
	Total	.390	26			