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Msc thesis

By

Gemeechu Regasa Geletu

Advisor:Shibiru Yadeta

July 2026

Nekemte ethiopia

WOLLEGA UNIVERSITY

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A THESIS SUBMITTED TO THE COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCE IN PARTIAL FULFILLMENT OF THE REQUIRMENT FOR THE DEGREE OF MASTER OF ANALYTICAL CHEMISTRY

MSc. Thesis

By;

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I **Mr. Gemechu Regassa Geletu** hereby declare and affirm that the thesis entitled **"Evaluation of Selected Physicochemical and Bacteriological Parameters of Spring Water in Gute and Gaba Jimata Town, East Wollaga Zone, Oromia, Ethiopia''** is my own work conducted under the supervision of shibiru yadeta. I have followed all the ethical principle of scholarship in the preparation, data collection, data analysis and completion of this thesis. All scholarly matter that is include in the thesis has been give recognition throuth citation. I have adequately cited and reference al the original source. I also declare that I have adhered to all principle of academic honesty and integrity and I have not misreperesented, fabricated, or falsified any idea/ data /fact source in my submission. This thesis submitted to partial fulfilement of requiremenet for degree from post graduated at wallaga university. I further declare that his thesis has not been submitted to any other institution any wgere for the award academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

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ABBREVIATIONS AND ACRONOMYS

AAS	:	Atomic Absorption Spectrophotometer
APHA	:	American Public Health Association
BOD	:	Biological Oxygen Demand
CES	:	Compulsory Ethiopian Standard
DO	:	Dissolved Oxygen
EC	:	Electrical Conductivity
GDWQ	:	Guidelines for Drinking Water Quality
GJSW	:	Gaba Jimata Spring Water
GSW	:	Gute Spring Water
ICP-MS	:	Inductively Coupled Plasma-Mass Spectrometry
ICP-OES	:	Inductively Coupled Plasma-Optical Emission Spectroscopy
pH	:	Power of Hydrogen
RSD	:	Relative Standard Deviation
SD	:	Standard Deviation
SDG	:	Sustainable Development Goal
TDS	:	Total Dissolved Solids
TH	:	Total Hardness
TS	:	Total Solid
TSS	:	Total Suspended Solids
WHO	:	World Health Organization

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ABSTRACT

Access to safe and clean drinking water is fundamental to the human health and socioeconomic development. However, rapid growth, urbanization and environmental pollution arising from agricultural, industrial and domestic activities have increasing threatened the quality of fresh water resource. This study was conducted to evaluate the physicochemical and bacteriological quality of spring water source in Gute and Gaba Jimata towns, East wallaga, zone oromia, Ethiopia. Water samples were collected from selected spring source and analyzed using standard analytical procedure to determine physicochemical parameter including pH electirical conductivity, total dissolved, total suspended solid, chloride, nitrate, phosphate, calcium, magnesium, iron, and manganese. In addition bacteriological analyses were performed to acess the presence of total coliform and fecal coliform bacteria. The main temperature values of the spring water sample were 22.00 ± 0.00 °C for Gute spring water and 21.00 ± 0.00 °C for Gaba Jimata spring water. The mean EC values were 93.63 ± 0.15 µS/cm for Gute spring water and 58.16 ± 0.20 µS/cm for Gaba Jimata spring water, while the corresponding TDS values were 58.66 ± 0.11 mg/L and 38.03 ± 0.15 mg/L, respectively. The TSS values were 0.98 ± 0.00 mg/L for Gute spring water and 1.00 ± 0.00 mg/L for Gaba Jimata spring water. The pH values ranged from 6.53 ± 0.06 in Gute spring water to 6.60 ± 0.10 in Gaba Jimata spring water, indicating slightly acidic to nearly neutral water conditions. Chloride concentrations were 80.46 ± 0.50 mg/L for Gute spring water and 76.91 ± 0.90 mg/L for Gaba Jimata spring water.The nitrate concentration were 1.29 ± 0.11 mg/L and 1.26 ± 0.00 mg/L for Gute spring water and Gaba Jimata spring water, respectively, whereas phosphate concentrations were 0.38 ± 0.13mg/L for Gute spring water and 0.26 ± 0.02 mg/L for Gaba Jimata spring water. The concentrations of calcium and magnesium ranged from 0.812 ± 0.03 to 0.95 ± 0.057 mg/L and from 0.78 ± 0.050 to 1.08 ± 0.026 mg/L, respectively. The concentrations of Fe were 0.058 ± 0.00mg/L in Gute spring water and 0.093 ± 0.00 mg/L in Gaba Jimata spring water, while Mn concentrations were 0.085 ± 0.00 mg/L and 0.094 ± 0.0t0 mg/L, respectively. The analyzed physicochemical parameter and trace metal concentration were compared with the guideline values recommende by the WHO and Ethiopian drinking water standards. All measuared parameters were found to be with in the permissible limits water standards. All measure parameter were found to be with the permissible limits for drinking water quality. Furthermore, bacteriological analysis revealed the absence of total coliform and fecal coliform bacteria in all sample, indicating that the spring water are macrobiological safe for human consumption. Over all the findings of this study demonstrate that the spring water source in Gute and Gaba Jimata towns are suitable for drinking and domestic purposes. Nevertheless continuous monitoring of water quality and seasonal assessment involving additional physicochemical and microbiological parameters are recommended to ensure the long term safety, sustanibility and protection of these water resource

Keywords: bacteriological analysis;Gaba Jimata town; Gute town; metal analysis; physicochemical parameter, spring water

1.INTRODUCTION

1.1 Background of study

Water is an essential for human survival and serves various domestic purposes including drinking, cooking, washing, bathing, and sanitation. To ensure public health, drinking water must be free from physical, microbiological, or chemical contaminant that may poses risk to human health. It should be free from harm ful microorganisms,toxic organicsubstance, and excessive levels of mineral that could adversely affect consumers. However, the quality of drinking water has deteriorated in many developing countries due to inadequate water treatment facilities, direct discharge in to water bodies, and poor management of water distribution system (Eliku & Sulaiman, 2015). Consequently, the provision of safe drinking water remains a major public health challenge, particalary in low income countries.

Access to safe and adequate drinking water is closely linked to the economic development and overall well-being of a nation (Genet & Desta, 2017). The process of water supply generally involves three major stages: water source collection, transportation or distribution, and point-of-use handling. Water may be obtained from sources such as lakes springs, ground waterr, or municipal supplies. After collection, the water is transported through distribution systems to consumers. The final stage, point-of-use water handling, is particularly critical because contamination may occur during storage and handling, even if the water was initially safe. Although household water treatment methods can improve water quality, improper storage and handling practice significantly increase the risk of contamibation (Mushi *et al*., 2018).

In many low incomes countries acess to clean water and adequate sanitation facilities remain limited (Demsash *et al*., 2023).A result millions of people suffer fromwater-, sanitation-, and hygene-related diseases such as diarrhea, trachoma and skin infections (Velleman *et al*., 2023). Water often reffered to as the universal solvent plays a vital role in biological process including cellular metabolism and growth (Soncini *et al*., 2023). However, water contaminated with human or animal waste may contain pathogenic microorganisms, including bacteria and viruses, which can cause disease such as cholera, typhoid fever, bacillary dysentery, and other waterborne infection (Santiago-Rodriguez *et al*., 2023). In

addition to microbial contamination, drinking water may also contain dissolved inorganic and organic pollutants that pose serious health risks to communities (Benny *et al*., 2023).

Acordingly to the WHO water borne and water-related disease account for a substantial proportion of illnesses worldwide (Shayo *et al*., 2023). Globally, approximately 144 million people rely on surface water source 7885 million uses unimproved drinking water sources and more than 2 billion people consume water contaminated with fecal things (Bogale, 2020). In Ethiopia, it is estimated that 60–80% of communicable diseases and about 50% of child malnutrition cases are associated with inadequateaccess to safe water, sanitation and hygene services WHO, 2017). Poor sanitation and hygiene practices, such as open defecation, contribute to fecal-oral disease transmission and diarrhea, which in turn aggravate malnutrition and child stunting (Angelakis *et al*., 2023).

Several studies have assessed the physicochemical properties of drinking water across various regions in Ethiopia. For instance, Abdisa and Abebaw (2014) investigated selected physicochemical and major chemical parameter of spring water in Iddo wara wale, located in the oromia region. Their study evaluated parameter such as temperature, electrical conductivity, ttal dissolved solid and alkalinity. Additionally, they analyzed major chemical parameters including sulfate nitrate, chloride, calcium, magnesium and phosphate (PO_4^{3-}). The result were compared with Ethiopia standards and World helth organization guidelines for drinking water quality. The parameter analyzed include pH, TDS, EC, chloride, total hardness (TH), magnesium, calcium, sulfate, nitrate, and phosphate. Tadele and Bedassa (2017) also investigated the physicochemical quality of drinking water in Nekemte Town, Oromia Region, focusing on turbidity, pH, EC, sulfate, nitrate, and phosphate levels. Their finding were compared with WHO and Ethiopian drinking water standard. In another study, Mezgebe *et al*. (2015) evaluated drinking water water quality in Mekelle City, Tigray region.

In addition to physicochemical assessments, several studies conducted in Jimma Zone, Adama Town, Bona District, Wogera Town, Nekemte Town, and Boloso Sore District reported bacteriological contamination of drinking water sources with indicator organisms such as total coliforms and fecal califorms (Yasin *et al*., 2015; Eliku & Suleiman, 2015).

Besides microbial contamination the occurrence of heavy metals in water resources has become an increasing public health concern because of their toxicity, persistence and bioaccumulation potential, even at low concentrations (Kapoor & Singh, 2021). Unlike many organic pollutant, heavy metals are not biodegradable and can accumulate in aquatic organisim and through the food chain. Therefore, untreated and unprotected water sources may pose serious health risk to communities that depend on them for drinking and domestic purposes.

Most residents of Gute and Gaba Jimata towns in Wayu Tuka District rely primarily on spring water for drinking and other household activities. Therefore, assessing the quality of these water source is essential to determine their safety and suitability for human consumption. According to the American public Health Association (APHA, 2005), physicochemical and bacteriological parameter are important indicators for evaluating water quality and public health safety. However, to best of our knowledge no previous study has selected assessed the selected physicochemical and bacteriological quality of spring water in Gute and Gaba Jimata towns, East Wollaga Zone, Oromia, Ethiopia. Therefore, this study aims to evaluate the selected physichochemical and bacteriological parameters of spring water in these towns.

1.2 Statement problem

Rapid population growth and urbanization have increase the demand for clean and safe rapid population growth and urbanization have increased demand for clean and safe water resulting in water shortages and declining water quality in many parts of Ethiopia (Salehi, 2022). In developing countries such as Ethiopia poor water quality and in adequate sanitation remain major public health challenges. Acess to safe drink water is essential for human health and preventin waterborne desease. However many communities continue to rely on untreated natural watersources for drinking and domestic purpose.

In the towns of Gute and Gaba Jimata, located in the East Wollaga Zone of Oromia, spiring water is the primary source of water for drinking and household activities. Although the local

population widely depends on these spring water sources, their quality is often assumed to be safe without regular monitoring and scientific evaluation. Such assumptions may expose communities to significant health risks because natural water sources are vulnerable to contamination from agricultural runoff, domestic waste disposal, human and animal activities, and naturally occurring geological materials. Contamination of spring water can alter its physicochemical characteristics, including pH turbidity ectrical conductivity, total dissolve solids and concentrations of chemical ions. In addition, untreated spring water may contain pathogenic microorganisms such as total coliforms and fecal coliforms, which indicate fecal contamination and increase the risk of water borne desease. Long term consumption of contaminated water can lead to serious problem and and reduced quality of life.

Although several studies have beenconducted on drinking water quality different parts of Ethiopia, there is limited information regarding the physicochemical and bacteriological quality of spring water in Gute and Gaba Jimata towns. The absence of such data makes it difficult for local authorities and health institutions to develop appropriate water quality management and public health protection strategies. Therefore, assessing the selected physicochemical and bacteriological parameter of spring water in these town is essential to determine its safety and stability for human consumption.

1.3. Objectives

1.3.1 General ojective

The main objective of this study was asses some selected physicochemical and bacteriological parameters of spring water in Gute and Gaba Jimata Town, located in the East Wollaga Zone of Oromia, Ethiopia

1.3.2 Specific objectives

- ✓ To determine the levels of some physical parameter of the spring water in Gute and Gaba Jimata Town.
- ✓ To quantify concentrations of selected chemical parameter in the spring water sources of Gute and Gaba Jimata Towns.

- ✓ To level the concentration of some selected metals (Mg, Ca, Fe and Mn) in the spring water of Gute and Gaba Jimata Town.
- ✓ To assess the bacteriological quality of spring water samples from Gute and Gaba Jimata Town by measuring total coliform and fecal coliform levels.
- ✓ To compare the physicochemical and bacteriological parameters of the water sample samples against against national and international drinking water guidelines

1.4 Significances of the study

Spring water is crucial sourse of drinking and domestic water for the residents of Gute and Gaba Jimata towns in the Wayu Tuka district of oromia, Ethiopia. The result of the physicochemical analysis of this spring water are significant as they enhance the community's understanding of safe water consumption practices, thereby promoting the cleanliness and safety of drinking water sources. Additionally, the study's findings have been valuable for district water suppliers, residents, public health officials, non-governmental organizations focused on water quality, and public administration, enabling them to respond swiftly to potential health outbreaks. Finally, thids study provide a base line for future researchers to compare the physicochemical parameter of drinking water in the area.

2. LITERATURE REVIEW

2.1. The Global Issue of drinking water quality

The quality of drinkingwater is critically important for public. Despite improvements over the past few decade, access tp safe drinkin water remains a significiant issue. According to the WHO, nearly 10% of the global population lacks access to improved drinking water source (WHO, 2017). On the united nation sustanale devolpment goal aims to insure universa to water and sanitation by 2030 (Jobbins *et al*., 2022). Waterborne infections, which cause diarrhea, result in nearly one million deaths each year, with the majority of victim being children under five years old (Bhuiyan *et al*., 2021). Additionally, chemical pollution poses an ongoing threat, particularly in industrialized nations and increasingly in low and middle income countries. Exposure to harmful chemical in drinking water can lead to various chronic desease, including cancer and cardiovascular issue, as well as negative reproductive outcomes and adverse effects on children's health (Ghafoor, 2024).

2.2. Overview of Drinking Water Contamination

The quality of drinking water is determined by its chemical, physical, and biological characterstcs (WHO, 2017). The suitability of water for consumption can be affected by pollution from human activities and natural source. Water pollutants include organic chemicals, inorganic toxic metals, domestic and agricultural waste, sewage, fertilizers, urban industrial waste, and thermal pollutants (Hasan *et al*., 2019). Contaminated drinking water can poses significant risk to human health improved water sources include piped water systems, protected wells, and rainwater collection. In contrast, unprotected sources consist of unprotected dug wells, tanker truck deliveries, and surface water is not safe.

Industrial effluents consist of various substances that vary by sector, including textile, steel, chemical, and metal processing industries. These effluents contain both organic and inorganic compounds Organic effluents are generated by several industries such as pharmaceuticals, organic dye , adhesives, soaps , synthetic detergent and fermentation (Gałązka *et al.,* 2019). Agricultural discharges represent a non-point source of pollution,

making them more challenging to manage and remediate due to their widespread dispersion. These discharges negatively impact the quality of both surface and groundwater. Key contaminants include fertilizer, pesticide, insectized, agricultural waste, plant and animals debris, inorganic material and manure slurry (Zahoor & Mushtaq, 2023).

Sewage is the primary source of contaminated water. It refers to wastewater that often contains various contaminants from households and businesses, including soap, detergents, glass, metals, human waste, garden debris, and sewage sludge (Needham & Ghosh, 2019). While industrial sewage carries used water from chemical procces, domestic sewage transports wastewater from residences. Untreated sewage contains numerous harmful contaminants such as lead, chromium, copper, mercury, cadmium, nitrogen, phosphorius, organic waste bacteria viruses and protozoa along with oils and greases

The use offertilizers can be safe when used correctly; however, excessive application or improper timing can lead to runoff that enters storm drains and ultimately pollutes lakes and streams. A fertilizer is any material, whether manufactured or natural, that provides one or more essential nutrients for plant growth. These substances can be organic or synthetic and, if misused, can be highly detrimental (Alalaf *et al*., 2023). Fertilizers are commonly utilized in agriculture due to their high phosphate and nitrogen content, which can harm the environment. Elevated levels of nitrogen fertilizers in groundwater pose risks to human health. Additionally, fertilizer runoff significantly impacts algal populations, leading to harmful algal blooms (Zahoor & Mushtaq, 2023). Water contamination in urban areas primarily results from runoff originating in populated regions. Due to limited soil permeability in urban environments, this runoff flows over highways and city landscapes. Pollutants in urban runoff include fertilizers, insecticides, plant debris, and waste from household chemicals. When these pollutants are carried by runoff through urban areas, they contribute to water quality degradation (Da Le *et al.,* 2023).

Organic molecules play a variety of roles in the chemical industry. A small number of pollutants that can enter drinks water from sourse pose a significant threat to public health (Dai *et al.,* 2019)

Inorganic pollutants resulting from human activities such as mineral acid, trace elements, iorganic salt metals and sulphate leach into groundwater aquifers. These pollutants are persistent in the environment and non-biodegradable, causing harm to aquatic ecosystem. Naturaly occurring inorganic pollutant are often the source of ground water contamination (Jain *et al.,* 2023).

The toxic metal linked metals such as aluminum arsenic barium cadmium chromium are linked to various health issues, such as diabet, hearing loss, immunological and hematological diseases, and several types of cancer. According to Chao *et al*. (2023), human activity are primary couse of hazardous metal pollution in water resources. Toxic metals are widespread in the environment, including drinking water food and other sources. They can enter water bodies through natural processes or as a result of pollution. Metals naturally dissolve in water when they come into contact with rock of soil (Numbere *et al.,* 2023).

2.3. Spring Water

A spring is natural phenomenon where ground water emerges from the earth subsurface before utilizing a spring as a water supply assessing its water quality is essential. Spring water is often regarded as a pristine and high-quality source due to its natural filtration process as it flows through layers of soil, sand, and porous rock. This filtration usually requires minimal to no treatment, especially when compared to surface water bodies like river and lake (Lone *et al*.,2021).However, springs are particularly vulnerable to contamination through two main pathways: natural factors and anthropogenic factors. Natural factors involve the interaction of groundwater with subterranean aquifers, where it dissolves ambient minerals from the surrounding rock. This process directly affects the spring's physicochemical profile, introducing ions such as calcium, magnesium, and chloride. If the local geology contains highly soluble minerals, the water may display increased hardness or salinity (Shrestha *et al*., 2023).Anthropogenic factors are prevalent in growing towns like Gute and Gaba Jimata. Here, urbanization, inadequate sanitation infrastructure, open defecation, and a lack of lined pit latrines can lead to the contamination of shallow groundwater with microbial pathogens. Additionally, agricultural practices in these areas often utilize synthetic fertilizers and animal manure. During heavy rainfall, surface runoff

and macropore infiltration can introduce excessive nutrient loads particularly nitrates and phosphates into the aquifer that supplies the spring. Consequently, water emerging at the spring head may pose significant bacteriological risks, including *E.coli* and total califormia in addition to altered physicochemical properties. Unfortunately, these sources are becoming increasingly contaminated. The expansion of industries in urban area and agricultural practice in rular are significant contributors to water pollution. This highlights the urgent need for rigorous and routine environmental monitoring (Adugna,2023).

2.4. The Issue of Quality Drinking Water in Ethiopia

The majority of Ethopian live in rular area yet 43% of these residents rely on unprotected drinking water source (Atumo Ante *et al*., 2023). Acording to the Ethiopian demographic and health survery, water treatment practices are very low with 84% of urban house hold and 92% of rular house hold nit treating their water. While nearly 65% of house hold have access to an improved source of drinking water only 6% of houe hold In Ethiopia utilize improved sanitation. Aditional, approcximately 9% house hold shareshare facilities, 53% use unimproved sanitary facilities, and 32% have no sanitation facility at all (Amlak *et al*., 2025).

Various findings indicate that the risk factor contributing to water quality deterioration in Ethiopia are primarily linked to poor water handling practices. Key risk factors include unhygienic water handling at the house hold leveland unsanitary environmental condition around water source reservoirs, and distribution lines. In many rural areas of Ethiopia, water contamination is often caused by washing cloth near water source and unrestricted animal access (Abebe *etal* 2025).

2.5. WHO Guidelines for drinking water quality

The primary reason for advocating the adoption of guidelines over international standards for drinking water quality, along with preventive management from catchment to consumer.

The development of narrowly defined norms or standards alone may have a limited effect on public health unless accompanied by supportive guidance that informs public health policy and water management practices. This guidance can cover various aspects, such as the development and application of laws, regulations, and standards; the progressive

implementation of these measures; monitoring, surveillance, and assessment; and information relevant to specific geographic areas or population groups (e.g., rural versus urban settings).The preparation of this type of guidance is not necessarily a part of the drinking water quality guidelines (GDWQ) itself. As a result, such supportive guidance may be published separately from the GDWQ and developed in collaboration with other agencies. A list of guidance materials related to the drinking water quality guidelines can be found in Reddy (2023). The decision to develop and publish this type of guidance largely depends on the lack of sufficient information from other sources, the potential impact this information could have on policy and practice, and the anticipated effects of such changes on public health (Brownson *et al*., 2018). Unlike some other components of the drinking water quality guidelines (GDWQ), the recovery and critical analysis of experience significantly enhance the overall quality of guidance on good practices (Chatwiriyaphong *et al*., 2024).

2.6. Ethiopian Drinking water quality standards

The compulsorly Ethiopian standard for drinking water specification out line the physical, chemical and bacteriological requirements for water intended for drinking and domestic purposes (Woreta *et al*., 2024). Similar to the new Sustainable Development Goal (SDG) target it defines quality and safe water as that meet all toxic bacteriological and organoleptic standard specific in CES-58 establishes minimum requirements for drinking water stating that any failure to meet the maximum permissible levels disqualifies the water for drinking and domestic use due to potential health hazards (None, 2022).

2.7. Chemical aspects of drinking water quality parameters

The quality of water for domestic, commercial, or agricultural use depends on various chemical parameters related to drinking water. When assessing water quality, it is essential to consider factors such as the reliability of the distribution network, source protection, and treatment efficiency (WHO, 2017).

2.7.1. Chloride (Cl^-)

Surface water bodies typically have lower chloride concentrations than sub-surface water, which is important for metabolic and physiological functions. High chloride levels can

damage structures and metallic pipes, as well as harm growing plant. Acording to WHO guidelines chloride concencentration shouldnot exceed 250mg/L (Meride & Ayenew, 2016). At this level, drinking water can have a salty taste, and individuals accustomed to higher chloride levels may experience laxative effects. Additionally, chloride concentration can indicate sewage contamination.

2.7.2. Nitrate (NO_3^-)

One of the primary contaminants affecting water quality is nitrate, particularly concerning newborns at risk of blue baby syndrome. Meride and Ayenew (2016) identify several source of nitrate, including the nitrogen cycle, industrial waste and nitrogenous fertilizer nitrogenous fertilizers. Nitrate leaches into surface water from percolating groundwater. While nitrate itself is not directly harmful, posing serious health risks. Surface water often becomes contaminated through the decomposition of organic matter and industrial wastewater, typically showing nitrate concentrations below 1mg/L whereas the EPA sets a threshold of 10 mg/L. Elevated nitrate levels above this threshold can lead to gastrointestinal problems.

2.7.3. Phosphate (PO_4^{3-})

Phosphate sources in surface waterways mainly include agricultural runoff containing inorganic fertilizers, industrial effluents, and sewage discharges that contain phosphate-based synthetic detergents. Spring water generally has negligible phosphate concentrations unless contaminated. Phosphorus is crucial nutrient for algea growth and significantly contributes to the eutrophication of lakes and reservoirs (Amanial, 2015). Eutrophication, primarily driven by elevated phosphate levels, indicates pollution in water bodies. Phosphates are only harmful to humans or animals at very high concentrations, and excessive phosphorus can lead to digestive issues (WHO, 2017).

2.7.4. Calcium (Ca)

Calcium is the most abundant ion in freshwater and plays a crucial a role in shell construction bone development and the precipitation of lime in plants. The taste threshold for calcium ions in drinking water ranges from 100 to 300 mg per liter, depending on the associated anion (WHO, 2017).

2.7.5. Magnesium

Magnisium is naturaly occurring element found I water and is the eighth most abundant element in the earth crust. It occurs in minerals such as magnetite and dolomite and is essential for the the proper functioning of two living organism. The human body contains approximately 25 grams of magnesium, with about 40% located in muscles and tissues and 60% in bones. Accordingly to WHO guidelines, the acceptable concentration of magnisumin water bodies is 50mg/L (Potasznik & Szymczyk, 2015).

2.8. Heavy Metals

Heavy metal contamination in water source especially ground water and surface water poses significant threats to human health. The expansion of urban area, industrial development and the use of chemical fertilizer in agricultural have lead to icrease level of toxic metal in aquatic ecosystem. This contamination occurs through pathways such as industrial wastewater, urban drainage systems, and storm water runoff. The presence of heavy metals in water reduces its quality. Various methods are employed to detect heavy metal contamination, including atomic absorption spectroscopy (AAS) (Punia *et al*., 2022).

2.8.1. Iron (Fe)

Anaerobic ground water can contain frrous iron at concentration of several milligram per litre without causing discoloration or turbidity when pumped directly from a well. How ever when exposed to the atmospheric, ferrous iron oxide to ferric xide resulting in an undesuirable reddish brown color in the water Additionally iron support the growth of bacteria which obtain energy from the oxidation of ferreous iron to ferric iron creating. When iron level exceded 0.3mg/L it can stain luandary and plumbing fixtures. Bellow this concentration there is typically no noticeable taste although turbidity and discoloration my occur. The WHO has not established a health based guideline for iron (WHO, 2017).

2.8.2. Manganese (Mn)

Manganese is naturaly found in in stream water and some surface waters, such as creeks and shallow dug wells. These metals often occur together in nature, so monitoring one can indicate potential issues with both. However, human activities can also lead to manganese

contamination in certain areas. In some regions, groundwater contains naturally high levels of iron, which can also enter drinking water through rusty steel or cast-iron pipes (Li *et al*., 2023).

Manganese exists in water in two forms: dissolved and suspended. In groundwater sourced from deep tube wells, manganese is typically dissolved and not visible. In contrast, surface water can contain manganese in either form. High levels of suspended manganese usually result in water that appears black or contains black flakes. While drinking water with elevated manganese concentrations may affect its acceptability, it has limited direct health implications. Nonetheless, manganese can alter the color of water, leading people to avoid it and potentially choose other, possibly contaminated, sources instead. Although humans require small amounts of manganese for good health, primarily obtained from food, both deficiencies and excesses can lead to adverse health effects (WHO, 2017).

2.9. Microbiological contaminants

Microbiological contaminats are microbes are organisms present in water that can poses serious health risks. These include bacteria from human and anima feces which can contaminate water sources (Delahoy *et al*., 2018). Waterborne diseases caused by bacteria, such as diarrhea, cholera, and typhoid are significant public health concerns. The presence coliforms in water indicate that other harm fuk bacteria my also be present. If coliform bacteria are detyected, an E,coli test is conducted to determine if the coliform of fecal orign. The presence of any E.coli makes the water unifit for drinking (AHemdan *et al*., 2020).

In addition to bacteria, viruses the smallest among pathogens can also contaminate water.The who classifies several water treatment viral pathogens as having moderate to high significance including adenovirus, arbovirus(Rao, 2021). Microbiological contamination with pathogenic microorganisms, along with their persistence, replication, and toxin production, has become a major concern for consumers, water industries, and regulatory agencies worldwide. Water microbial contamination of water can occur at any stage of the water cycle. Hazard analysis critical control point principle controlling raw materials, and maintaining the cold chain in both industry and retail. This contamination not only involves the growth of undesirable microbes but also the production of toxic substances resulting from their metabolism, such as mycotoxins (Awuchi *et al*., 2021).

Closely related to microbial contamination are losses of water due to spoilage or waste. With the global human population continually growing, the demand for water is rising.. Microbial toxins produced by various human enteric pathogens facilitate their entry and proliferation within human hosts. In contrast, many microbes adapted to aquatic environments release toxins as a survival mechanism or during cell autolysis. Endotoxins, in sufficient quantities, can cause non-specific responses in humans, such as fever. Using the Limulus lysate procedure, which is sensitive to picogram levels of endotoxin, researchers have detected this substance in the drinking water of most cities studied (Ibrahim *et al*., 2017).

2.10. Bacteriological Quality Water Problem in Ethiopia

Most Ethiopians consume water that is unsafe for drinking. For example, a community based survey and cluster randomized study in rulal Ethiopia found that stored drinking water at home was contaminated with fecal coliform (Daba *etal.,* 2025). This issue may stem from the low priority given to rural and pastoral communities (Mburu *et al*., 2023). Consequently, rual area and pastoral communities are most affected by water borne infection (Kumar *et al*., 2022).

Many households rely on unimproved water source and significant number do not treat before drinking. This may be linked to low perception of water quality, associated health risk (Anthonj *et al*., 2022). In conventional environmental assessments, legislators evaluate pollution at the outlets of all pollutant sources through fieldwork operations. However, some qualitative measurements are conducted at specific points in the aquatic environment using environment-based standards. Measurements of urban sewage depend on water quality modeling of chemical, physical, and biological properties (Erbe *et al*., 2002). Improper handling practices are a major cause of drinking water quality deterioration, despite the role of natural causes (Mishra, 2023).

2.10.1. Fecal Coliforms

Fecal coliforms are a critical parameter for evaluating the safety of drinking due to the associated risk of infectious diseases. Their presence indicates contamination from the waste of mammals and birds, suggesting the potential existence of harmful bacteria and viruses. Fecal coliforms are linked to waterborne diseases such as chlorea typhoid and other diarrheal illnesses (Fazal-ur-Rehman, 2019).

2.10.2. Total Coliforms

The total coliform group of bacteria is an unreliable indicator of fecal contamination, as many species can grow and persist in various environments, including water distribution systems, without having a fecal origin. The term "total coliforms" refers to bacteria commonly found in soil, water contamineted surface runoff, and the excrement of humans and animals. A crucial step before consuming water is to test it for microbiological purity (Logan, 2023). Examining both total and fecal coliform counts can help determine the presense of additional harmful bacteria in water (Alizadeh & Nowzari, 2023).

2.11 Health impacts of contaminated drinking water

Contaminants in drinking water that exceed allowable limit can lead to various health issues depending on the specific pollutants involved. In fact, the ingenstion of contaminat drinking water account for 80% of desesase in devolping countries. This contamination not only poses health risks but also has economic repercussions, resulting in lost work hours and increased hospital expenses. Additionally, it negatively impacts literacy rate particalay among children, who are the most affected groups (Alsubaie *et al*., 2022).

Table 1: Some selected water quality characteristics used for testing quality of water and their sources and potential health effect (Tong *et al*., 2021)

Parameter	Sources	Potential helth risk
Temperature	Due to chemical reaction hot waste water	Influence chemical biochemical biological of aquatic system effect on solubility on solubility essential gases
TDS	From the presence of all dissolved salt	Undesirable taste gastro intestinal irritation

EC	Due to different dissolved solid	High conductivity increase corrosive nature of water turbidity
pH	Due to different dissolved gase and solid	Bitter test corrosion affect mucus membrane
Fluoride	Presence of mineral salt	Dental and skeleton
Nitrate	Run off, fertilizer septic tank	Effect on infant symptoms include shortness of breath blues baby syndrome
phosphate	Waste water from detergent effluent work	Stimulate microbial growth rancidity moulds growth algal eutrophication

2.12 Physicochemical properties of water

Physical and chemical are parameter that do not identify specific chemical species but serve as indicator of how water may impact its uses. These properties include temperature electrical conductivity total dissolved solid chemical oxygen demand hydrogen ion concentration alkalinity hardness and sodium adsorption ratio (WHO, 2017). Physicochemical quality parameters are crucial not only for assessing the degree of pollution but also for selecting the best water source and treatment methods. The discharge of industrial effluents into nearby water bodies poses a significant threat to water quality and its intended purposes. The standard values recommende by the WHO and Ethiopian standard for selected physicochemical parameters of drinking water are summarized in Table 1.Additionally, physicochemical parameters are influenced by climatology hydrological and geological factor. They encompass both the chemical and physical componnents of water quality (Dohare *et al*., 2014).

Table 2: Physicochemical Parameter of drinking water (WHO, 2017, CES)

S.No	Parameters	WHO permissible limits	CES
1	Temperature	30 ºC	30 ºC
2	Electrical conductivity	750 (µS/Cm)	-
4	power of Hydrogen	6.5-8.5	6.5-8.5
5	Total Dissolved Solid	500 mg/L	1000 mg/L
7	chloride	250 mg/L	250 mg/L
8	Nitrate	50 mg/L	50 mg/L

10	Phosphate	5 mg/L

2.12.1. Temperature

Temperature significantly affects the acceptability of various inorganic substances and chemical contaminants that can alter flavor; generally, cold water is preferred over warm water (Yamanaka *et al*., 2017). Higher water temperature promote growth of micro organism worsening, smell, color, and rust (Gamawa & Okpanachi, 2023). Additionally, temperature regulates all biological and biological process such growth multipilication decay amd menilozation by controlling solubility gasses. Due to effluent pollution, which raises water temperatures and reduces dissolved oxygen solubility, water temperature exceeding 27oC are considered "unsuitable" for public consumption (Agudelo-Vera *et al*., 2020).

2.12.2. Electrical conductivity (EC)

According to Moussaoui *et al*. (2023), one effective method for assessing water cleanliness is measuring its electrical conductivity, which indicates the capacity to carry electric current. Most inorganic substances, when dissolved in water, act as good electrical conductors. In contrast, organic compounds that remain dissolved in aqueous solutions show very poor or negligible conductivity when subjected to voltage. Changes in conductivity can indicate water contamination from discharges or other sources. Hussain *et al*. (2023) explain that a conductivity meter (sensor) is used to measure water conductivity. This measurement reflects the extent of ion-assisted electron transport in the water. The conductivity is influenced by temperature and pH, as water molecules dissociate into ions. Certain gases, like carbon dioxide, readily dissolve in water and form ions, which systematically affect both conductivity and pH. The Ethiopian Central Statistical Agency classifies electrical conductivity (EC) as low (less than 150 µS/cm), moderate (150 to 500 µS/cm), high (500 to 800 µS/cm), and extremely high (above 800 µS/cm) (Pal *et al*., 2015).

2.12.3 Total dissolved solid

According to Maliki *et al.* (2020), Total Dissolved Solids (TDS) primarily consists of inorganic salts dissolved in water, including calcium, magnesium, potassium, sodium, bicarbonate, chlorides, and sulfate. The operational definition indicates that solids should

generally be small enough to pass through a filter with nominal pores no larger than two micrometers (Angelakis *et al.,* 2023). The TDS value is influenced by the factor such as host rock,climate,and the duration of ground water presence of in the geological matrix. The concentration of dissolved salts affects both the physicochemical properties and visual appeal of water. High levels of dissolved solids can restrict the solubility of gases, such as oxygen, and diminish water's suitability for industrial, agricultural, and drinking purposes. Additionally, elevated TDS levels can impact osmoregulation in freshwater organisms and increase water density. Consumers may find TDS levels above 1200 mg/L unappealing, particularly those who need to limit salt intake, such as individuals with severe hypertension, diabetes, or those on dialysis. Furthermore, high TDS concentrations can interact with heavy metals, reducing water clarity and hindering photosynthesis.

2.12.4 Total suspended solid

TSS, or total suspended solids refers to the solids comprising mineral and organic materials that are retained on a 1.2µm filter. These solids remain indefinitely suspended in the solution and cannot pass through a 2 µm filter. TSS significantly affects water purity, as the presence of additional sediments reduces clarity. Moreover, suspended particles can harm groundwater quality when they are introduced through runoff from industrial, urban , or agricultural area (Henrietta *et al.,* 2023).

2.12.5 pH

pH scale, which ranges from 0 to 14, is used to measure the acidity and alkalinity of solution based on the concentration of hydrogen and hydroxide ion. Pure water has pH 7 considered as neutral. Values bellow 7 indicated acidity while above indicate basicity. Typically the ph of water fall between 56 and 8.5 . while with low pH can be hazardous while with high pH can test bitter. Accordingly to WHO guideline the optimal pH for water shoul be 6.5 and 8.5 It's important to assess both pH and chlorine residual simultaneously, as chlorine's effectiveness as a disinfectant is influenced by pH levels (Yehia *et al*., 2021).

Table 3: Parameters selected for the study and apparatus used for methods of analysis (Aljeddani & Mohammed, 2023).

NO	Parameter	Method
1	Ph	pH meter
2	Temperature (°C)	Thermometer
3	Electrical conductivity (mS/cm)	Conductivity meter
4	Total dissolved solids (mg/l)	Conductometry
5	Total suspended solids (mg/l)	filtration processes

3.MATERIAL METHODS

3.1Description of the study Area

The study conducted in the wayu tuka district located in the East wallaga zone of the oromia region in westrn Ethiopia (Figure 1). Wayu tuka district is between 8º 56N and 9° 7'N latitude and 36º 32E and 36° 48'E longitude. Its lies approximately 322km west of Addis Ababa and 12km eat of Nekemte the znal capital city of East wollega. The altitude in the area range from 1700 to 2200 metre above the sea level with in an average annual rain fal of 2400mm. the population of wayu tuka district is estimated 75,970residing in 15, 930 house hold about 95% of the population live the rular area and relies on substance farming for their livelihoods.(Temesgen, 2023). The district cover an area of 28,952.795 hectare and cosist of 12 kebele the smallest administrative unit which include ten rural area and two urban center (Megersa *et al*., 2013). The district receive annual rain fall ranging 1,000 to 2400mm and experience annual temperature between 14 °C and 26 °C.

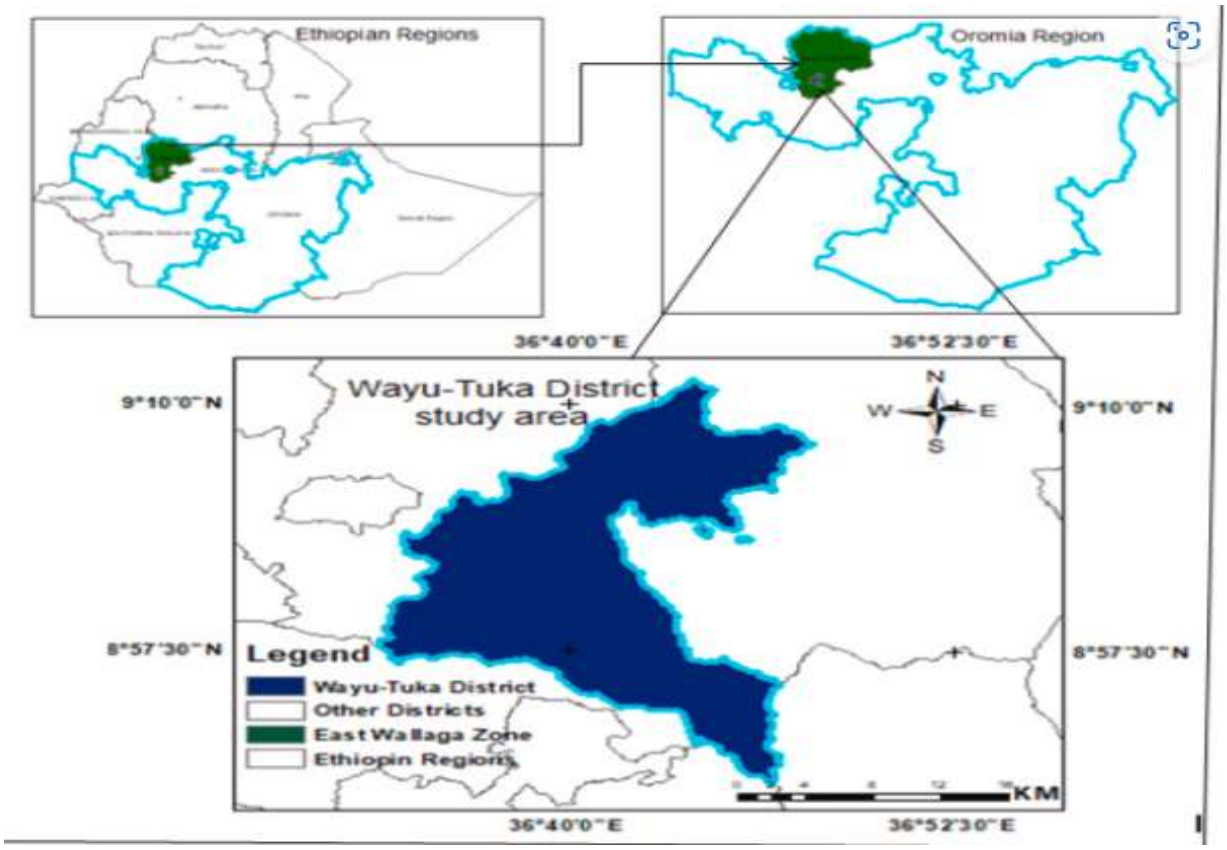

Figure 1: Map of Wayu Tuka district (Bekere *et al*., 2023)

3.2. Chemicals and Reagents

HNO_3 (65%), HCl (37%), $AgNO_3$ (99.9%), K_2CrO_4 (99%), $[(NH_4)_6Mo_7O_{24}\cdot 4H_2O]$ (99.3%), $N_2H_6SO_4$ (99%), KNO_3 (99%), $Ca(NO_3)_2\cdot 4H_2O$ (99%), $Mg(NO_3)_2$ (99.5%), $Fe(NO_3)_2\cdot 9H_2O$ (99.9%), and $Mn(NO_3)_2\cdot 4H_2O$ (98.5%) all from Loba Chemie Pvt Ltd, India), KCl (99.5%, Titan Bio Tech Ltd, India), buffer tablets (pH 4 and 7), KH_2PO_4 (98%), Samir Tech-Chem pvt Ltd, India) were used in the study. Aditional water was employed for sample preparation and equipment cleaning prior to analysis throughout laboratory procedures.

3.3. Instruments and Apparatus

Two one-liter clean polyethylene plastic bottles, washed with acid and deionized water before sample collection were used as sample holder. An icebox was employed for preservation during sample transport. An analytical balance measured the mass of chemicals

used in the titration method. Various laboratory equipment was utilized, including different sizes of burettes, Erlenmeyer flasks, polyethylene bottles, beakers, pipettes, volumetric flasks, and measuring cylinders. A hotplate was used to heat water samples for digestion, while a refrigerator stored the water samples at 4 °C. temperature was measured using a thermometer (0-100 °C). Electrica conductivity and total dissolved solids were determined using microproccesor based conductivity /TDS meter. pH was measured with portable pH meter. The concentrations of Ca, Mg, Fe, and Mn were analyzed using an Atomic Absorption Spectrometer at Holeta Agricultural Research.

3.4. Sample Collection and Preservation

The WHO's (2017) recommendations for the composite sampling technique for assessing drinking water quality were followed in collecting samples. Water sample from Gute and Gaba Jimata springs were collected in April 2025 and coded as GSW and GJSW, respectively, in 1 L clean, dry polyethylene bottles, which were labeled accordingly. One milliliter of pure HNO_3 was immediately added to each of the three bottles to analyze specific physicochemical properties later (Zhang *et al.*, 2022). Sterilized glass bottles were labeled and kept cold in an icebox while the water sample were transported aseptically to the chemistry department ofWollaga University for examination. The samples were properly tagged, air-tightened, and stored in a refrigerator at temperatures beloow 4° until complete analyses were conducted using established procedures (Cobbina *et al.*, 2015).

3.5. Analytical Procedures for Physicochemical Assessment

Water possesses a variety of physically and chemically characterstic that influence its quality and treatability. Conducting physical and chemical tests on drinking water is essential to ensure that treated water safe and paltable, as well as to monitor the effectiveness of different water treatments for a safe drinking water supply.

Table 4: Methods of Determining Selected chemical Parameters

S.No	Parameters	Methods
1	Chloride	Argentometric Method
2	Nitrate	UV Vis Spectrophotometric method
3	Phosphate	UV Vis Spectrophotometric method

Table 5: Instrument for determining selected physicochemical parameters

S.No	Parameters	Instrument to be used
1	Temperature	mercury thermometer
3	Electrical conductivity	portable conductivity meter
4	Total dissolved solid	Microprocessor conductivity/TDS, Temperature meter
5	pH	portable pH meter
6	Ca and Mg concentration	Atomic Absorption Spectrophotometers

Physicochemical quality parameters of water are crucial for assessing pollution levels and selecting the most suitable source and treatment methods. The discharging of industrial influents bodies poses a significant threat to water quality, compromising its intended uses. Key parameters measured include temperature, pH, conductivity total dissolved solids and total hardness (Dohare *et al*., 2014).

3.6. Standard Procedures for physical Parameters Analysis

The water temperature was measured using mercury in glass thermometer (Table 5), which was dipped into a 50 mL water sample and left for one minute before recording the temperature (Awogbami,2023). Electrical conductivity was measured with a microprocessor-based conductivity/TDS meter (Table 5), which was calibrated using a 0.01 M KCl calibration solution. Subsequently, 50mL of the water sample was analyzed (Zhao, 2020). To measure total dissolved solids (TDS), 50mL of the water sample using Whatman number 1

filter paper in a conical flask. The TDS of the filtrate was measured with the microprocessor-based conductivity/TDS meter (Amanial, 2015).

Total suspended solid were determined by first weighting the filter paper alone. The filter paper was then placed in a filtration apparatus, and 50 mL of the water sample poured in to it. After filtration, the filter paper containing the retained material was placed in an evaporating dish and heated for one hour at 104°C Following this, the material was removed from the an oven and placed in a desiccator for 20 minute. The wegth of sample was measured with an electronic balance and the resut were recorded using using equation (1) (Jensch *et al*., 2021).

$$TSS\left(\frac{mg}{L}\right) = \frac{\text{A} - \text{B}}{\text{water sample vL (mL)}} * 1000 \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where weigthing of filter paper in mg= B weigth of dried residue plus filter paper (in mg) = A Weight of residue (in mg) = A - B. the pH of the water sample was measured using pH meter that was calibrated with a buffer solution. In this study 50mL of the water was placed in ab eaker and the pH meter electrode were immersed in the sample until the reading stabilized (Olal, 2023).

3.7. Chemical Parameter Analysis

3.7.1. Determination of Chloride Ion (Cl^-)

Chloride was determing using the argentometric titration methods (Table 4). A 50 mLsample was placed in a conical flask and 2ml of potassium chromate was added to rhe solution. The sample was then titrated with 0.02N silver nitrate until preistence brick red color appread, indicating the end point of the titration. The chloride ion concentration was calculated using Equation 2.A blank titration involving 50ml of distillled water was performed (APHA, 2005).

$$Chloride\left(\frac{mg}{L}\right) = \frac{(\text{A} - \text{B}) \times \text{N} \times 35.5 \times 1000\text{mL/L}}{\text{V of the sample in mL}} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where A is the Volume of titrant silver nitrate used for sample B is the volume titrant silver nitrate used for the blank, V is the volume of the sample in ml and N is the normality of silver nitrate.

3.7.2. Determination of Nitrate (NO_3^-)

NO_3^- was measured using a UV spectrophotometer screening technique (Table 4). A 50ml aliquot of the filtered clean sample was mixed with 1ml of HCl solution. To create NO_3^- calibration standards ranging from 0 to 7 mg/L, intermediate nitrate solutions in the following volumes were diluted to 50 mL: 0, 1, 2, 4, 7, 15, and 35.0 mL. Both the NO_3^- standards and samples were processed identically. The absorbance was measured using redistilled water, which was set to zero absorbance. NO_3^- measurements and interference assessments from dissolved organic compounds were conducted at wavelengths of 220 nm and 275 nm, respectively (Lal *et al.,* 2023).

3.7.3. Determination of Phosphate ion (PO_4^{3-})

To a 50ml volumetric flask 40ml of spring water sample was combined with 4ml of ammonium molybadate and 1.6 ml of hydrazine sulfate. The mixture was then brought to the mark with deionized water. It was placed inwater bath and heatd at 60oC for 30 minute during which blue color developed due to formation of phosphomolybdate complex after cooling the absorbance was measured using a double UV-visible spectrophotometer (DRAWELL) at 740 nm(Table 4), with deionized water serving as the experiment blank solution. The analysis was conducted in triplicate (Oladeji *et al.*, 2016).

3.8. Water Sample Digestion

Fifty ml of each spring water sample were taken and 5 militre of HNO_3 and HCl were added. The mixture was digested at temperature below 80oC for one hour until a clear solution was obtained. The clear solution was the diluted to final volume of 50ml in a volumetric flask to create a solution of known concentration. Ablank digestion was also performed using the same method (Aga and Birhane 2014).

3.9. Metals and Heavy Metal Analysis

To determine metal cations, the atomic absorption spectrometer (AAS) was calibirated using four standard solution for each metal of interest.. These working standard were prepared by diluting intermediated standard solution containing 10mg/L with dionized water. The intermediate standard solution were created from 100mg//L stock solutions for each metal. Following the instrument's operation manual the working standard were apirated sequentially into the spectrometer and their absorbance was recorded. Calibration curves were the ploted for each metal and heavy metal standard using absorbance against concentration (Teshome, 2021). The precision of the result was assessed using relative standard deviation calculated frm the result of multiple sample and triplicate reading for each sample (Techane *et al*., 2019).

$$RSD = \frac{SD}{X} x100 \ldots\ldots 3$$

where: RSD= represent relative standard deviation SD standard deviation and X mean value , and.

3.9.1. Spiking Samples

For spiking,1.25ml of 0.65 mg/L Ca salt 1.25 of 0.8mg/L salt of 18m/L Fe salt and 2ml of 10 mg/L Mn salt were added simultaneously to another beaker containing the same amount of sample. The spiked sample were the digested using the same methds and reagent as described for the sample (Adventini *et al*., 2021).

3.10. Recovery Analysis

The reliability and efficiency of the optimized procedure for analyzing ions in spring water sample were validated using the spiking methods as no certified reference method was available. To assess the efficiency of optimized procedure, known concentrations of each metal of interest were added to the spring water sample (equation 4).

$$\%\ \text{Recovery} = \frac{\text{Spiked Concentration} - \text{non spiked concentration}}{\text{added concentration}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

3.11. Bacteriological Analysis

The membrane filtration method was employed to quantify total and fecal coliforms (APHA, 2005). Growth absorbent pads were placed in the base of petri using a sterile pad dispenser and then soaked in Lauryl Sulfate Broth. Next, 100ml of each water sample was filtered through a 0.45 membirane filter using vacuum tube equipment, the filtrate ere subsequanttlt transfere to the absorbent pads soaked in broth. Prior to incubation, the petridish waere resuscitated for four hr at 37oC to recover physiologically stressed coliforms. Following this, the plate were incubated at 37oC and 44 oC for 24 hr to count and record fecal and total coliforms (Adesakin *et al.,* 2020).

$$\frac{\text{number of colonies}}{100\text{ml}} = \frac{\text{caliform colonies counted}}{\text{mLsammple filtred}} \times 100 \qquad (4)$$

3.12. Data Analysis

Using Microsoft Excel 2010, the data were logged, arranged, and condensed. Descriptive statistics was performed Utilizing SPSS version 16.

4. RESULT AND DISCUSSIONS

In this study sample were collected from Gute and Gaba Jimata spring water sources. The physicochemical parameters, metalconcentrations, and bacteriological parameters of the samples were analyzed. The mean value of some physicochemical parameter are presented in Table 6, while the concentrations of metal ions are shown in the table 7.

Table 6: Result of physicochemical parameters of spring water samples (mean ± SD) (n = 3)

S/N	Parameters	Sample sites		Standards	
		GSW	GJSW	CES	WHO
1	Temperature (°C)	22.00 ±0.00	21.00 ± 0.00	30	30
2	EC (µS/Cm)	93.63 ± 0.15	58.16 ± 0.20	1500	1000
3	TDS (mg/L)	58.66 ± 0.11	38.03 ±0.15	1000	1000
4	TSS (m/L)	0.98 ± 0.00	1.00±0.00	-	-
5	pH	6.53 ± 0.06	6.60 ± 0.1	6.5-8.5	6.5-8.5
6	Cl^- (mg/L)	80.46 ± 0.50	76.91 ± 0.9	250	250
7	NO_3^- (mg/L	1.29 ± 0.11	1.26 ± 0.00	50	50
8	PO_4^{-3} mg/L	0.38 ± 0.13	0.26 ± 0.02	5	-

Key: GSW=Gute Spring water, GJSW=Gaba Jimata Spring water

4.1. Physical parameter Analysis

4.1.1. Temperature

The temperature reading for spring water sample presented in table 6. The mean temperatures for GSW and GJSW were 22.00 ± 0.00 °C and 21.00 ± 0.00 °C, respectively. Both samples fell with in the permicible limits set by the WHO and ES. Since water temperature influences chemical reactions, dissolved oxygen levels, and microbial activity, the observed values imply that the spring waters are suitable for domestic use from a temperature perspective. Furthermore, the finding study was conducted in Ethiopia, particularly the report by Mekonen (2020) in Bure, Ethiopia, thereby supporting the reliability and acceptability of the present results.

4.1.2 Electrical conductivity

The average EC value presented in Table 6 were 93.63 ± 0.15 µS/cm for GSW and 58.16 ± 0.20 µS/cm for GJSW. These findings indicate that both spring water samples comply with the safety standard set by the WHO and ES. GSW exhibited a higher EC than GJSW, likely due to GSW containing more dissolved ions, such as calcium and magnesium. This difference may result from the natural geological formations that the spring water traverses, which dissolve more minerals. Similar findings were reported in a study by Amanial (2015) conducted in Arba Minch, Ethiopia, which also identified comparable EC values for GSW. Conversely, the EC values recorded for GJSW in the current study align with those of drinking water sample from other cities in Ethiopia (Yasin *et al*., 2015; Meride & Ayenew, 2016).

4.1.3 Total dissolved Solid (TDS)

The TDS values recorded inthis study were 58.66 ± 0.11m/L for GSW and 38.03 ± 0.15 mg/L for GJSW (table 6). This finding aligns with a study by Kassegne and Leta (2020) conducted in the Amhara region Ethiopia, further supporting the results of the current study. The TDS values observed in both spring water sample low and with in recommended standards for drinking water quality. The slightly higher TDS value in GSW may be associated with increased dissolution of naturally occurring minerals from surrounding geological formations. Overall, the low TDS concentrations indicate good palatability and acceptable water quality, suggesting that both spring water sources are suitable for domestic purpose and drinking (Kant *et al*., 2018).

4.1.4 Total Suspended Solid/TSS

In this study, the TSS values for springwater were found to be 0.98 ± 0.00mg/L for GSW and 1.00 ± 0.00 mg/L for GJSW (Table 6).These concentration are lower tha those reported by Amanial (2015) in the study conducted in Arbaminch, Ethiopia. The low TSS values recorded in both spring water samples indicate minimal suspended matter and good physical water quality, suggesting that the water sources are relatively free from particulate contamination and suitable for domestic use (Shigut *et al*., 2017).

4.1.5. pH

In the current study, the mean pH values for the drinking water samples were 6.53 ± 0.06 for GSW and 6.60 ± 0.10 for GJSW (Table 6). These values are within the perimissible imit established by the WHOand ES. The pH values of both spring water samples indicate that the water is slightly acidic to near neutral, making it suitable for drinking. These results suggest that the water sources are chemically stable and unlikely to cause any adverse effects associated with excessive acidity or alkalinity (Pinheiro *et al*., 2021).

4.2. Chemical Parameter Analysis

4.2.1 Chloride (Cl^-)

The chloride ion concentrations measured in this study were 80.46 ± 0.50 mg/L for GSW and 76.91 ± 0.9 mg/L for GJSW (Table 6). These values fall within the permissible levels set by both ES and WHO. A similar chloride concentration was reported by Kassa (2015) in a study conducted in Goya Village, Tigray, Ethiopia. The slightly higher chloride concentration in the GSW sample compared to GJSW may be due to sewage discharging near sampling site. The chloride concentrations indicate that water is not significantly impacted by chloride pollution. While GSW exhibited a slightly higher chloride level, the concentration remains safe for domestic and drinking purposes, posing no potential health risk(Granato *etal,2015*).

4.2.2 Nitrate

In the current study, the nitrate concentrations measured in the sample were 1.29 ± 0.11 mg/L for GSW and 1.26 ± 0.00mg/L for GJSW (Table 6). These levels are significantly lower than the WHO and ESA recommended limit of 50mg/L for drinking water. Additionally, the mean nitrate concentrations found in this study were lower than those reported by Abera etal. (2022) in Mekelle City, Ethiopia, and Kassegne & Leta (2020) in the Ankober district of Ethiopia. However, they closely matched the results obtained by Bekele *et al*. (2018) in Damot Sore, Southern Ethiopia. Nitrates enter freshwater systems primarily through sewage discharge and runoff from agricultural fields (Cao *et al*., 2022). The very low nitrate concentrations observed in both spring water samples indicate minimal contamination from agricultural activities and sewage sources.

The results suggest that the spring waters are safe for drinking with respect to nitrate content and are unlikely to pose health risks associated with excessive nitrate exposure (Yakovlev etal., 2015).

4.2.3 Phosphate (PO_4^{3-})

In the study, the phosphate levels in the drinking water samples were recorded as 0.38 ± 0.13 mg/L for GSW and 0.26 ± 0.02mg/L for GJSW (Table 6). Across the entire site, phosphate concentrations remained below the maximum acceptable limit of 5mg/L set by theWHOThe phosphate content in both spring water sample closely aligned with findings from previous research conducted in towns in Ethiopia, including Jimma Nekemte (Duressa *etal.,2019*), and Robe (Shigut etal., 2017). Groundwater can contain phosphate from source such as fertilizer-treated, detergents,and household wastewater. The low phosphate concentrations found in both spring water samples indicate minimal contamination from agricultural and domestic waste sources. These values, which are significantly below recommended standards, indicate good water quality and confirm that the spring waters are safe for drinking and domestic use with respect to phosphate content (Rawat & Joshi,2019).

4.3. Metal Analysis

As shown in table 7 the correlation coeffient obtained from the calibiration for each metal was greater than 0.99 indicating an excellent correlation between the concentration and absorbance of each metal. The concentration of thr working standard the correlation cofficients for the calibration graphs of each metal are listed in table 7. . The high correlation coefficients obtained for all calibration curves (Appendix Figure 2, 3, 4, 5, 6) demonstrate the reliability, accuracy and suitability of the analytical methods used for metal determination.The successful detection of calcium and magnisum in both spring water sample further confirms the effectiveness of the digestion and measurement procedures employed in this study (Addis & Abebaw,2017).

Table 6: Working standard solutions, correlation coefficients and magnesium concentration of water samples

Metal analyzed	Working Standard	R^2	GJSW Mean ±SD (mg/L)	GSW Mean±SD (mg/L)
Ca	0.25, 0.5, 1.0, 2.0	0.9982	0.812±0.003	0.95±0.057
Mg	0.5, 1.0, 1.5, 2.0, 2.5	0.9989	0.78±0.050	1.08±0.026
Fe	4,8,12,16,20	0.9939	0.093±0.00	0.058±0.00
Mn	1,1.5,2,2.5	0.9949	0.094±0.00	0.085±0.00

The highest calcium concentration recorded to spring water was 0.95±0.057 mg/L at GSW, while the lowes was 0.812 ±0.03 mg/L at GJSW (Table 7). Both concentrations fall within the acceptable limits set by WHO ana ES standards fo drinking water (WHO, 2017; ESA, 2013). Calcium ions (Ca^{2+}) can naturaly occur in ground waterthrugh the diddolution of carbonate mineral and decomposition of sulfate, phosphate and silicate minerals. The concentration of magnesium ions (Mg^{2+}) in the spring waters was 0.78±0.050 mg/L for GJSW and 1.08±0.026 mg/L for GSW (Table 7). The result indicate that both spring water samples contained magnesium ion permicible unit limit of 50 mg/L set by WHO and ESA standard for drinking water (WHO, 2017; ESA, 2013). The magnesium and calcium concentrations observed in this study were comparable to those reported in the Gofa Zone, Ethiopia, by Dube and Kanido (2025). The results suggest that the spring waters are safe with respect to Ca^{2+} and Mg^{2+} content and reflect the natural geological composition of the study area (Vishwakarma *etal.,2018*).

I nthis study the concentaration of Fe in GSW and GJSW were found to be 0.058±0.00 mg/L and 0.093±0.00 mg/L respectively (Table 7). The permissible limit for iron, as set by WHO (2021), is 0.3 mg/L (Table 7). Therefore, the iron concentration in this study are within the permissible limits established by WHO (2017) and may be considered safe for drinking water. This finding aligns with results from spring water collected during the wet season in the Ankober district of Ethiopia (Kassegne & Leta, 2020) for GJSW, and the Fe concentration recorded for GSW corresponds with findings in the Mecha district, Amhara, Ethiopia (Lewoyehu, 2021). The permissible limit for managanase in water sample is 0.1mg/L (WHO, 2017). Both spring water sample fell with in this permissible limit. Similar

result were reported Arbegona district of Sidama, Ethiopia (Gedifew *et al*., 2025), and in Assesa, Oromia, Ethiopia (Hiko, 2022). The result indicate that the water water safe is safe to drink regarding these trace metals. The observed values are consistence with finding from previous study conducted in various region of Ethiopia, reinforcing the idea that these metals occur naturally at low and acceptable levels(Asefa *et al*.,2024).

4.4 Recovery test

The coefficient of the procedure was evaluated by adding known concentration of metal on to water sample. The samples were then digested and subsequently diluted with deionized water. They were analyzed using the same procedure as that used for the original water sample. Triplicate spiked sample were recorded, similar to the original sample the recovery values for the current sample water sample are presented in table 8

Table 8: recovery test for the optimized procedure of spring water sample

Metals	Unspiked sample(mg/L)	Amount added(mg/L)	Spiked sample	%Recovery
Ca	0.95±0.057	0.65	1.54	90.7±0.04
Mg	1.08±0.026	0.8	1.82	92.5±0.03
Fe	0.093±0.00	18	17.534	96.8±0.07
Mn	0.085±0.00	10	9.511	94.26±0.01

The recovery of metals in the spiked laboratory control sample were as follows: 90.7±0.04 % for Ca, 92.5±0.03 % for Mg, 96.8±0.07 % for Fe, and 94.26±0.01 % for Mn. These recovery results are with in acceptable range for a reliable study, demonstrating the accuracy of the method and confirming the reliability of the measured metal concentration levels (Sabzkoohi *et al*., 2023).

4.5. Bacteriological Analysis Results

The WHO and Ethiopian standards for drinking water quality stipulate that total coliform/TC and fecal coliform/ FC should not be detected 100ml of drinking water (WHO, 2017). In this study, the result indicated that both spring and water sample from GSW and GJSW showed no presence of total coliform or fecal coliform, confirming their safety for drinking (Table 9). Comparable findings were reported in previous studies conducted in the Ankober district in amara region Ethiopia (Kassegne & Leta, 2020). Additionally, all water sample examined in this study had lower levels of TC and FC compared to other regions of the country, such as the Munessa district (Gadiso *etal,2020*), wegeda town (sitotaw *etal 2020*), and Adama town (Eliku & Sulaiman, 2015). Overall, the bacteriological quality of allawater sample in this study not met national and international standard for drinking water interm of TC and FC WHO,2017.

Table 7. Bacteriological quality of spring water samples (CFU/100 mL)

Parameters	GSW	GJSW
Total coliform/100 mL	0	0
Fecal coliform/100 mL	0	0

5. CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

In conclusion, the present study on the evaluation of selected physicochemical and bacteriological parameter of spring water in Gute and Gaba Jimata towns, East Wollaga Zone, Oromia, Ethiopia, revealed that the overall quality of the spring water was with the possible limit recommened for drinking water. The physicochemical parameters analyzed the were found to comply with the standards established by national and international guidelines, indicating that the spring water is suitable for human consumption. Similarly the concentaration of selected trace metal were bellow the maximum allowable limit suggesting that the water sources are safe from heavy metal contamination and do not pose significant health risk to the consumers.

Furthermore, the bacteriological analysis showed no detectable contamination by harmful microorganisms, confirming the microbiological safety of the spring water sample. The absence of bacterial contamination indicates that water source are hygienically safe and suitable for drinking purposes. Therefore, the spring waters of Gute and Gaba Jimata towns can generally be considered safe for drinking and domestic use. However, continuous monitoring and proper management of water sources are recommended to maintain their quality and protect public health in the future.

5.2. Recommendation

From the current study some of the physicochemical parameter and heavy metal was analyzed, but not all of the representative parameters of the water sample was done. Therefore, the current study forwards the following recommendations.

- Some physicochemical parameters like (dissolved oxygen, alkalinity, BOD, fluoride, nitrite, ammonia etc.), other metals and heavy metals (Pb,Cd,Ni, Co,Cu,Hg, As, Na, K, etc.) parameter of the spring water sample of the study are better if analyzed by other researches.
- Additionally, other researcher are recommended to use other analytical techniqueas like inductive coupled plazma mass spectrometer, inductive coupled plasma optical emission spectroscopy for analysis of heavy metal in spring water sample of the study
- Furthermore, future studies involving seasonal variations and additional water quality parameters are recommended to provide more comprehensive information about the long term safety and sustainability of the spring water sources.

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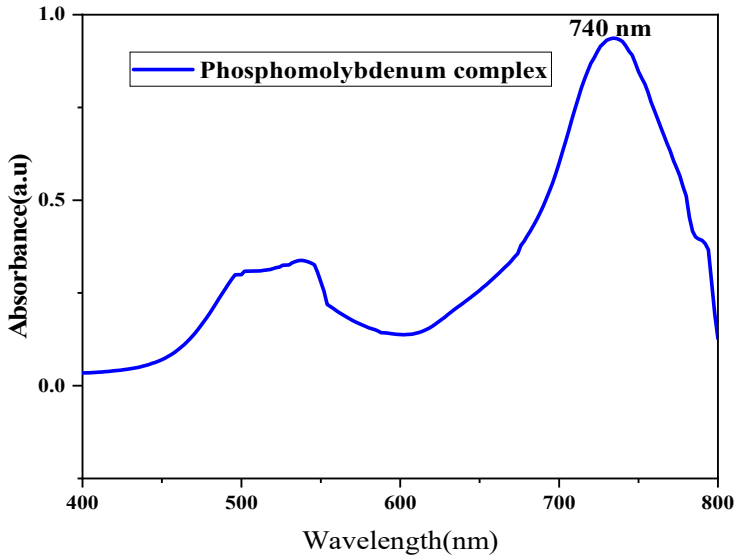
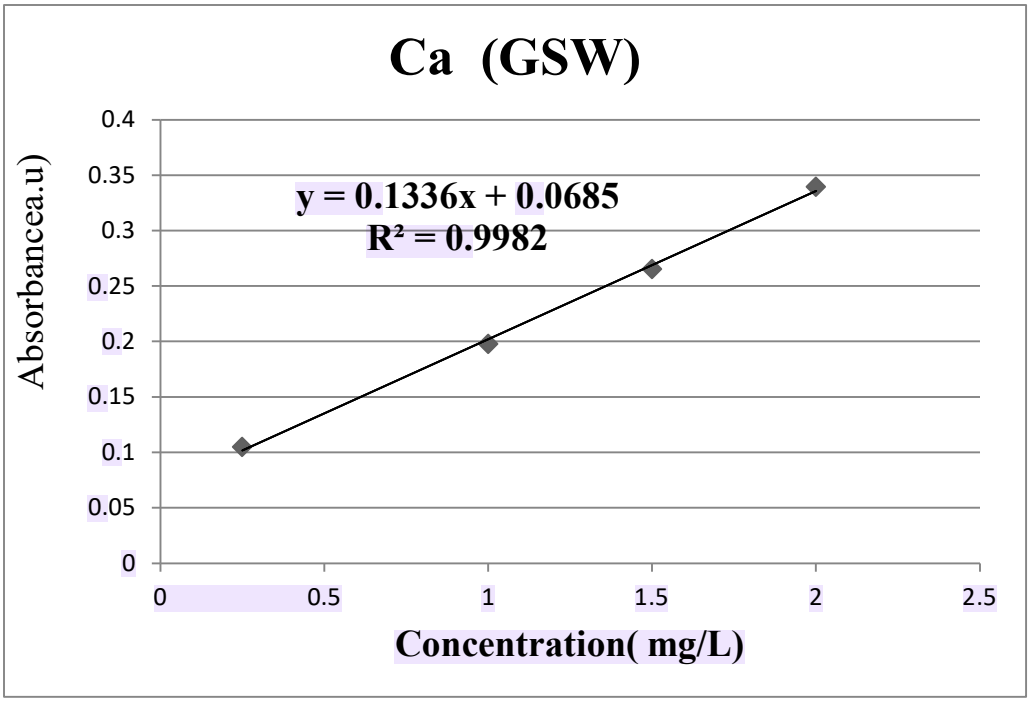
7. APPENDIX

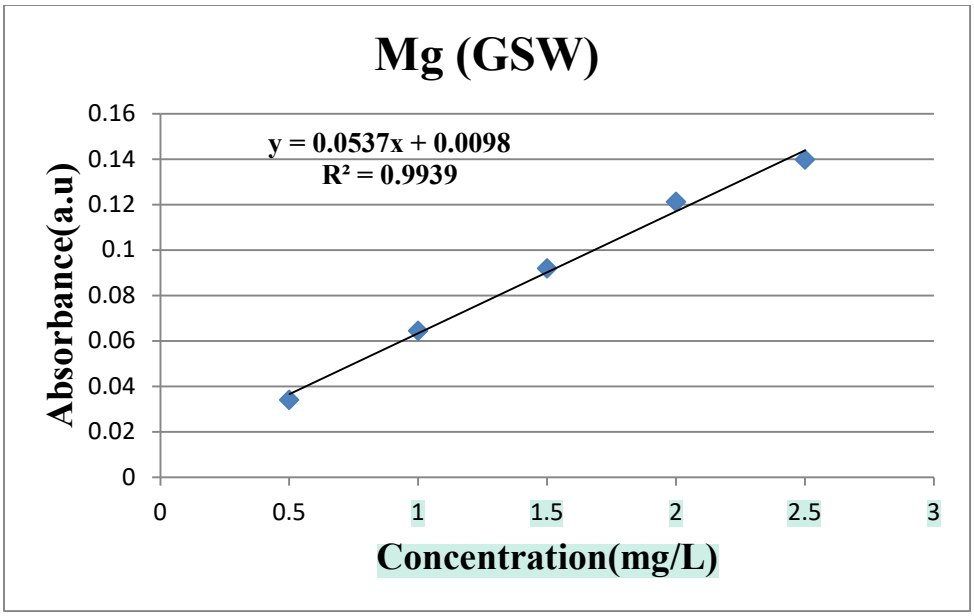
7.1. Appendix Figures



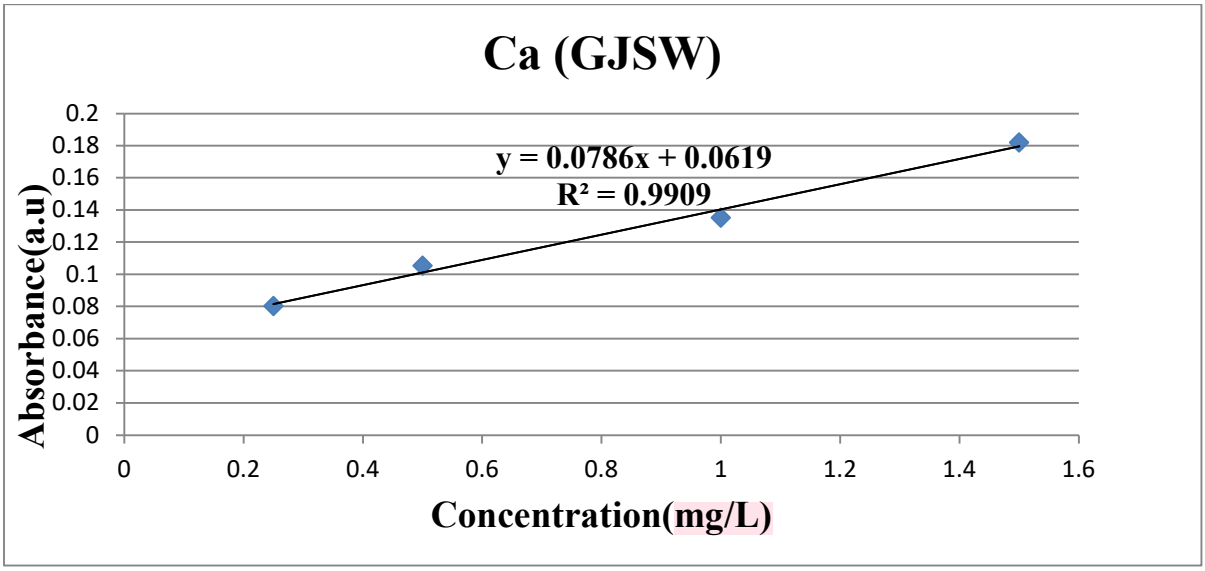
Appendix Figure 1: UV-Visible spectrum of phosphomolybdenum complex



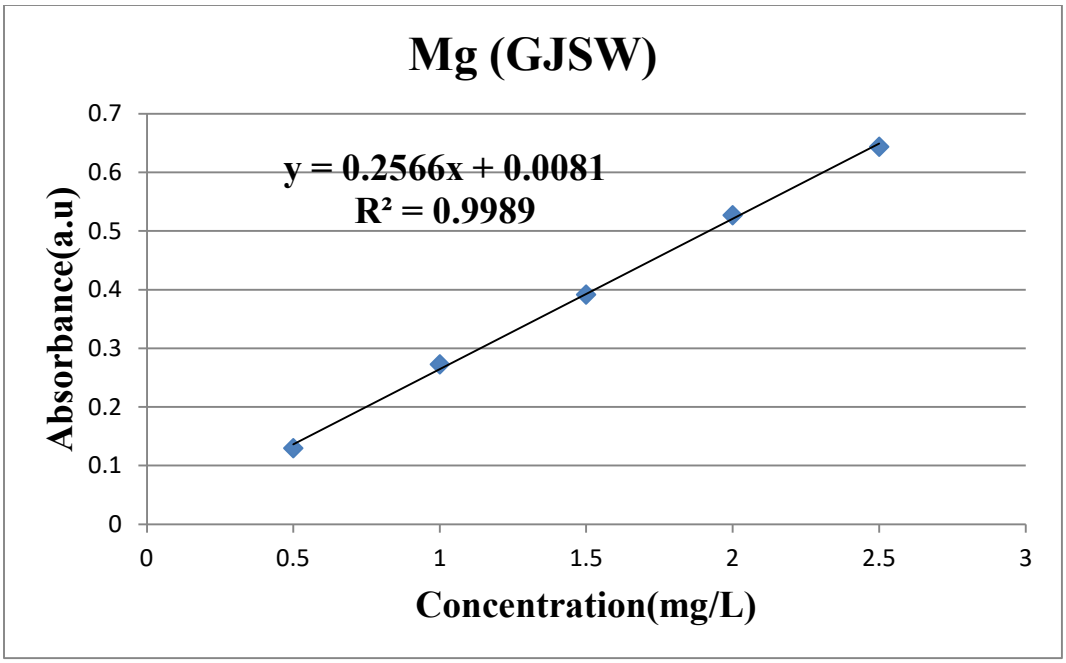
Appendix Figure 2: Calibration curves of calcium for Gute Spring water



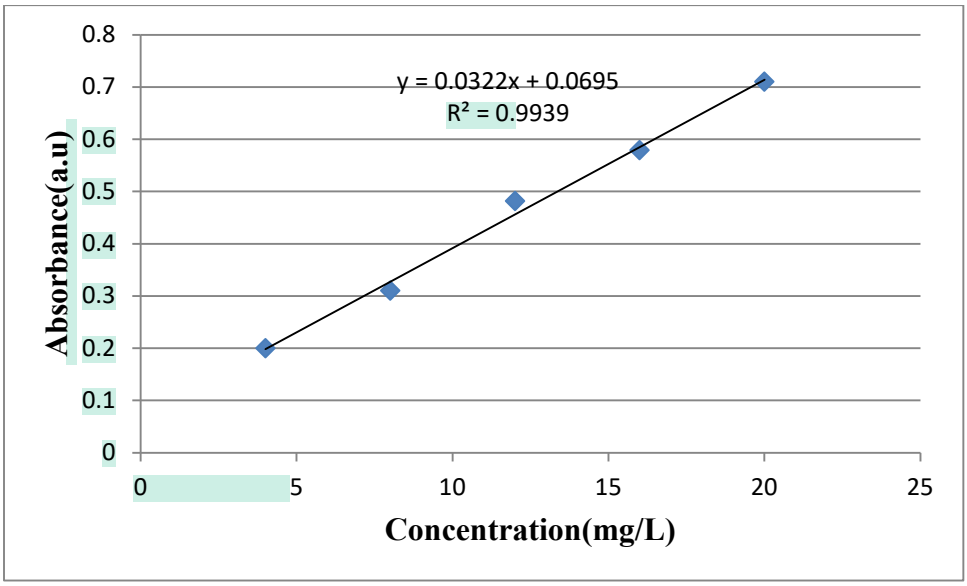
Appendix Figure 3: Calibration curves of magnesium for Gute Spring water



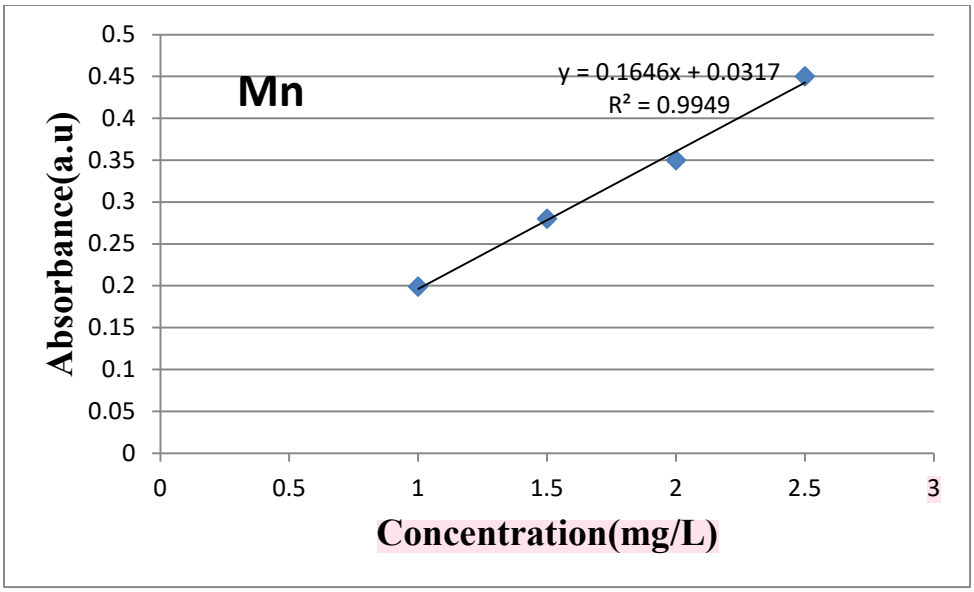
Appendix Figure 4: Calibration curve of calcium for Gaba jimata spring water



Appendix Figure 5: Calibration curves of magnesium for Gaba Jimata spring water



Appendix Figure 6: calibration curve for iron in spring water



105

Appendix Figure 7: Calibration curve for manganese in spring water