

WALLAGA UNIVERSITY

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

SCHOOL OF GRADUATE STUDIES

ASSESSMENT OF SELECTED PHYSICO-CHEMICAL AND BACTERIOLOGICAL PARAMETERS OF DRINKING WATER FROM SOURCE, RESERVOIR AND HOUSEHOLD IN AMURU TOWN, HORRO GUDURU WALLAGA, ETHIOPIA

MSc Thesis

By:

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June ,2026

Nekemte, Ethiopia



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A Thesis Submitted to the College of Natural and Computational Sciences in Partial Fulfillment of the Requirements for the Degree of Master of Science in Inorganic chemistry

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DECLARATION

I declare hereby that this thesis entitled "Assessment of Selected Physico-Chemical and Bacteriological Parameters of Drinking Water from Source, Reservoir and Household in Amuru Town, HorroGudurruWallaga, Ethiopia“was conducted by LetaLebeta under my supervision. As a thesis research advisor, I recommended it be accepted in partial fulfillment of the requirement for the award of the degree of Master of Science in Inorganic Chemistry by the School of Graduate Studies, Wallaga University, through the College of Natural and Computational Sciences.

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STATEMENT OF THE AUTHOR

I, Mr. LetaLebeta, hereby declare and affirm that the thesis entitled"Assessment of Selected Physico-Chemical and Bacteriological Parameters of Drinking Water from Source, Reservoir and Household in Amuru Town, Horro Gudurru Wallaga, Ethiopia "is my own work conducted under the supervision of Dr. Raji Feyisaat Wallaga University. I have followed all the ethical principles of scholarship in the preparation, data collection, data analysis, and completion of this thesis. All the scholarly material that is included in the thesis has been given recognition through citation. I have adequately cited and referenced all the original sources. I also declare that I have adhered to all principles of academic honesty and integrity, and I have not misrepresented, fabricated, or falsified any idea, data, fact, or source in my submission. This thesis is submitted in partial fulfillment of the requirement for a degree from the Postgraduate Studies program at Wallaga University. I further declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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ACRONYMS AND ABBREVIATIONS

APHA	**:**	American Public Health Association
CFU	**:**	Colony Forming Unit
EC	**:**	Electrical Conductivity
EDTA	**:**	Ethylene Diamine Tetra Acetic acid
FC	**:**	Fecal Coliforms
GDWQ	**:**	Guidelines for Drinking Water Quality
NTU	**:**	NepheloTurbidimetric Units
SPSS	**:**	Statistical Package for the Social Sciences
TA	**:**	Total Alkalinity
TC	**:**	Total Coliforms
TCU	**:**	True Color Units
TDS	**:**	Total Dissolved Solid
TH	**:**	Total Hardness
TSS	**:**	Total Suspended Solid
WHO	**:**	World Health Organization
WSP	**:**	Water Safety Plan

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ABSTRACT

Water is vital for Life on this planet. Thus, the aim of this study was to assess the selected physicochemical and bacteriological parameters of drinking water from source, reservoir and household in Amuru town, Horro Gudurru Wallaga, Ethiopia. A total of 14 physicochemical parameters namely turbidity (by turbidity meter),temperature (by thermometer),Electrical conductivity and Total dissolved solid (microprocessor conductivity/TDS meter), Total Suspended Solid (filtration method), pH(pH meter), Total alkalinity A(titration method),Total Hardness (EDTA titration method),F^-(ion selective electrode), Cl^-(argentometric titration), Mg,NO_3^-,SO_4^{2-} and PO_4^{3-}were determined by spectrophotometric method)and two bacterio logical parameters FC, TC(membrane filtration method) were analyzed in order to understand the characteristic and quality status of the three drinking water. The analyzed values are given as Turbidity 1.523±0.137NTU (SC), 1.433±0.152NTU(R) and 1.933±0.152(HH), temperature (17.6 66±0.577^{0}C(SC), 17.066±0.105^{0}C(R) and 17.600±0.100^{0}C(HH), EC(60.6±0.01µs/cm(SC),599 ±0.030(R), 60.8±0.170µs/cm(HH), TDS(39.16±0.026mg/L(SC),20.20±0.026(R),and 29.50±0.0 11mg/L(HH), TSS(0.125±0.003mg/L(SC),0.240±0.002mg/L(R), 0.401±0.01mg/L(HH), pH(5.1 43±0.083(SC), 4.85±0.000(R) and 4.86±0.000(HH), TA(23.06±0.333(SC), 31.36±0.122(R) 13.40±0.010(HH).The drinking water samples taken from source, reservoir and household in Amuru town had no FCs or TCs. Descriptive statistics were used to describe data, while Pearson correlation was used to determine the influences of the physicochemical variables. From the total sample analyzed, most of the sample complies with the water quality guidelines of Ethiopian permissible limit, and WHO, except the temperature and pH values. Further studies should be conducted in different seasons, considering other water quality parameters such as physical, chemical, and bacteriological properties, before using it for drinking and domestic and purposes.

Keywords: Physicochemical parameters, Bacteriological parameters, water quality,Amurutown,source,reservoir,household.

1. INTRODUCTION

1.1. Background of the study

Water is fundamental to sustaining life on Earth, and ensuring its safety for human consumption is critically important.Drinking water must possess appropriate chemical, biological, and physical characteristics. It should not contain harmful microorganisms, excessive organic compounds, or mineral substances that could pose health risks. Additionally, potable water should be at an acceptable temperature, appear clean and clear, and be free from unpleasant tastes, smells. However, inadequate treatment facilities, the direct discharge of untreated sewage in to rivers, and poor management of water supply and distribution systems have contributed significantly to the deterioration of drinking water quality (WHO, 2023).

The availability and quality of drinking water in both rural and urban areas play a crucial role in a nation's economic development and overall public health (Genet &Desta, 2017). Supplying safe water to consumers generally involves three main stages. The first stage is sourcing the water, which may come from lakes, springs, groundwater, or municipal supplies. At this point, it is important to assess whether these sources are naturally protected or easily accessible to contamination. The second stage involves conveying the collected water to users through various means, such as municipal distribution networks or alternative delivery systems. The final and most critical stage is point-of-use handling at the household level. This includes either consuming the water directly or storing it for later use. Even when water has been treated through a household purification system, it remains vulnerable to contamination if it is not properly handled and stored (Mushi*et al.*, 2018).

In many developing countries, access to safe drinking water and adequate sanitation remains limited for a significant portion of the population (Demsash*et al.*, 2023). This lack of essential services contributes to widespread health problems, with millions affected by diseases associated with poor water, sanitation, and hygiene conditions, such as trachoma, dermatological infections, and diarrheal diseases (Vellaman*et al.*, 2023). Water is fundamental to life, functioning as the primary medium in which biochemical reactions, cellular metabolism, and growth occur. Owing to its remarkable capacity to dissolve numerous substances, it is often described as the universal

solvent (Soncini S*et al.,* 2023). However, when water intended for drinking is contaminated with fecal matter or urine from humans or animals carrying pathogenic microorganisms, it can facilitate the spread of waterborne diseases. These include cholera, typhoid fever, bacillary dysentery, viral infections such as those caused by adenoviruses and retroviruses, and other serious illnesses (Santiago-Rodriguez *et al.,* 2023).

Water obtained from various sources may also contain dissolved inorganic and organic substances that pose potential risks to public health (Benny *et al.,* 2023). The World Health Organization (WHO) estimates that waterborne and water-related diseases contribute to as much as 80% of illnesses worldwide (Shayo*et al.,* 2023). Globally, approximately 144 million people rely on untreated surface water for drinking, 785 million use unimproved water sources, and more than 2 billion consume water contaminated with human feces (Bogale, 2020). Furthermore, many healthcare facilities in low- and middle-income countries do not have access to improved water supplies, adequate sanitation services, or basic handwashing facilities with water and soap (Alemu*et al.,* 2023).

In Ethiopia, 60%-80% of communicable diseases are attributed to limited access to safe water and in adequate sanitation and hygiene services while approximately 50% of under nutrition is associated with environmental factors such as poor hygiene and lack of access to water and sanitation. Furthermore, poor hygiene practices, including open defection, contribute to child illness, under nutrition, and stunting (UNICEF, 2023). Open defecation facilitates the transmission of fecal–oral infections, including diarrheal diseases, which both worsen existing malnutrition and contribute to its development (Angelakis*et al.,* 2023).

Several studies have examined the bacteriological safety of drinking water across different regions of Ethiopia, revealing widespread contamination. For instance, in the Jimma Zone of southwest Ethiopia, all analyzed drinking water samples were positive for both total coliforms and fecal coliforms (Yasin*et al.,* 2015). In Bahir Dar city in northwest Ethiopia, 77% of samples were contaminated with total coliforms and classified as high risk (Tabor *et al.,* 2011). In Adama town, 44.2% of water samples contained fecal streptococci, while 28.9% tested positive for coliform bacteria (Eliku&Sulaiman, 2015). In southern Ethiopia, 86% of drinking water samples in Bona District failed to comply with WHO standards (Berhanu&Hailu, 2015).In Wogera town

in northern Ethiopia, fecal coliform contamination levels ranged from 82.1% to 86.8% (Felek*et al.,* 2018). Likewise, in Nekemte town in western Ethiopia, all samples (100%) were positive for total coliforms, and 37% were contaminated with fecal coliforms (Duressa *et al.,* 2019). In Boloso Sore District, 91% of household water samples and 44% of source water samples tested positive for fecal coliforms, with many samples categorized as high risk (Alemayehu*et al.,* 2020; Gizachew*et al.,* 2020).

Residents of Amuru Town obtain their drinking water primarily from several unprotected springs used directly, as well as from a single borehole that supplies water through a piped system. Consequently, households rely on either protected springs or the borehole as their main sources of tap water. According to official reports from the town's health office, waterborne diseases rank among the ten leading causes of illness in the area. In the current year alone, approximately 60% of patients visiting local health facilities were diagnosed with diarrhea, dysentery, or typhoid fever. In response to the absence of prior scientific investigations in the area, this study aimed to assess the physicochemical and bacteriological quality of drinking water from the source to the household level in Amuru Town, located in HorroGudurruWallaga Zone of the Oromia Region, Ethiopia, using standard analytical methods. The results highlight the seriousness of drinking water contamination in the town, underscoring the need for immediate intervention by responsible authorities and encouraging further research by the scientific community.

1.2. Statement of problem

Ethiopia is recognized as one of the countries facing significant challenges related to poor water quality. Compared to other Sub-Saharan African nations, it has relatively low coverage of improved drinking water supply and sanitation services, estimated at 57% and 28%, respectively (Ayeta*et al.,* 2023). The use of contaminated surface water sources has been strongly associated with acute microbial diarrheal diseases, including cholera, salmonellosis, and shigellosis, among other water-related infections, thereby creating a major public health burden (Noor, 2023).(Belihu*et al.*2023) reported that approximately three-quarters of childhood illnesses in Ethiopia are attributable to communicable diseases linked to unsafe water and poor water management practices. In the study area, a substantial proportion of patients seeking care at

health facilities were diagnosed with typhoid fever, dysentery, or diarrhea. Despite these concerns, no prior research has specifically investigated the physicochemical and bacteriological quality of drinking water from source to household level in Amuru Town. Therefore, this study aimed to assess the microbiological and physicochemical characteristics of drinking water in the selected sites. Although several investigations have been conducted in different parts of Ethiopia to evaluate drinking water quality (Tadesseet al.,2023), many findings indicate that measured physicochemical and bacteriological parameters often exceed the permissible limits set by national standards and the World Health Organization. These studies emphasize the need for corrective measures, including improved infrastructure and enhanced public awareness. Accordingly, this research sought to examine the physicochemical and bacteriological quality of drinking water in Amuru Town, HorroGudurruWallaga Zone, Ethiopia, at the source, reservoir, and household levels.

1.3. Objectives of the study

1.3.1. General objective

- To assess 1the physicochemical and bacteriological parameter quality of drinking water from source to household level in Amuru Town, Oromia Region, Ethiopia, in order to determine potential health risks and informs public health interventions.

1.3.2. Specific 1objectives

- To quantify pH, turbidity, temperature, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), total alkalinity, and total hardness in drinking water samples collected from the source, reservoir, and household levels in Amuru.
- To evaluate bacteriological quality of water sample from source, reservoir and household using total coliform and fecal Coliform in AmuruTown, Ethiopia.
- To compare the physicochemical and bacteriological parameters of drinking water in source, reservoir and the household of Amuru Town, Ethiopia.
- To compare the physiochemical and bacteriological parameters of drinking water from source, reservoir and the household in Amuru Town with WHO standard and the Ethiopian Standards.

1.4. Significance of Study

The primary purpose of this study was to examine the factors influencing the quality of drinking water in Amuru Town. By evaluating physical, chemical, and bacteriological parameters, the study provides a framework for understanding water quality and its role in reducing waterborne diseases and associated health challenges. The findings are valuable for the local community, as they highlight safe water consumption practices and promote proper maintenance of drinking water sources to ensure continued safety and cleanliness. Additionally, the results offer critical insights for woreda water supply authorities, local residents, public health professionals, non-governmental organizations involved in water and sanitation, and governmental agencies, enabling timely interventions to prevent potential health hazards. Finally, the study establishes a reference point for future research, facilitating comparative analyses of the microbiological and physicochemical characteristics of drinking water within the region and in similar contexts.

2. LITERATURE REVIEW

2.1. Water Sources, Water Quality, and Human Health

Potable water can be obtained from a variety of sources, including surface water, groundwater, and natural reservoirs (Nuwanka&Gunathilaka, 2023). However, even water sourced from what is considered a high-quality supply may still pose health risks if it does not meet the established safety standards set by local authorities. The Joint Monitoring Programmer of the World Health Organization (WHO, 2017) has developed an updated classification system for water sources to track both accessibility and safety. This classification distinguishes between types of sources and highlights the importance of not only providing improved water supply but also ensuring that it is reliably safe for consumption. To address gaps in improved water coverage, the Sustainable Development Goals (SDGs) now incorporate two additional categories: basic and safely managed water services, emphasizing both accessibility and the quality management of water sources (WHO, 2017)

Access to an adequate supply of clean water is essential for human survival, and a lack of this resource is widely recognized as a major factor that diminishes quality of life (Shah *et al.*, 2023). Water quality is typically assessed through three main categories: physical, chemical, and biological parameters, all of which directly influence its suitability for human consumption. These parameters provide important information about the condition of a water source and its safety for daily use. Potable water, often referred to as drinking water, must meet specific bacteriological, chemical, and physical standards to be considered safe for both cooking and drinking purposes (Atumo*et al.,* 2023). According to the World Health Organization, water is classified as safe when it poses no significant health risks throughout the supply system or at the point of consumption (Selak*et al.,* 2023).

2.2. Water Contamination and Sources of Water Pollution

Groundwater can become polluted when hazardous substances from human activities infiltrate it, making it unsafe for consumption (Bisht*et al.,* 2023). The movement and dispersion of contaminants through aquifers can spread pollutants over wide areas, affecting large portions of the water supply. As surface water percolates through soil layers, salts, minerals, and organic matter are often dissolved and absorbed, which increases the concentration of dissolved solids in the water. In some locations, the natural mineral content of groundwater reaches levels that render it unsuitable for drinking or agricultural use without prior treatment.

2.3 Groundwater and Sources of Pollution

Groundwater, a critical source of fresh water, resides in the spaces between soil and rocks beneath the Earth's surface (Dandge&Patil, 2022). This water supply is vulnerable to contamination from both natural processes and human activities. Various pollutants threaten groundwater quality, including organic chemicals, inorganic substances, toxic metals, domestic and agricultural waste, sewage, fertilizers, urban runoff, industrial discharges, and thermal pollutants (Hasan*et al.,* 2019).

Industrial Effluents: Industrial wastewater varies by sector, including textile, steel, chemical, and metal processing industries. These effluents contain both organic and inorganic substances. Organic pollutants originate from industries such as pharmaceuticals, dyes, cosmetics, detergents, pesticides, textiles, paper manufacturing, oil refining, metal processing, and fermentation (Gałązka*et al.,* 2019).

Agricultural Discharges: Agricultural runoff is a widespread, diffuse source of pollution that contaminates both surface and groundwater. Fertilizers, pesticides, insecticides, agricultural waste, and organic debris from plants and animals contribute significantly to water pollution in agricultural regions (Zahoor&Mushtaq, 2023).

Sewage and Domestic Waste: Sewage, which originates from households and businesses, is a primary source of water contamination. It contains soaps, detergents, metals, human waste, garden debris, and sludge. Industrial sewage typically contains chemicals specific to manufacturing processes, while domestic sewage carries waste from residential areas. Untreated

sewage introduces heavy metals, nitrogen, phosphorus, organic matter, pathogens, oils, and greases into water bodies, posing significant health risks when discharged into rivers, lakes, or oceans (Needham &Ghosh, 2019; Vijayalakshmi*et al.,* 2023).

Fertilizers: Although fertilizers support plant growth, improper use can lead to runoff that contaminates water sources. Fertilizers, which supply essential nutrients like nitrogen and phosphorus, are often responsible for environmental issues such as algal blooms caused by nutrient overload in aquatic ecosystems (Alalaf*et al.,* 2023; Zahoor&Mushtaq, 2023).

Runoff from Urban Areas: Urban runoff is a form of non-point source pollution caused by rainwater flowing over impervious surfaces such as roads and rooftops, carrying pollutants like fertilizers, insecticides, plant debris, and household chemical waste into water bodies (Dale*et al.,* 2023).

Organic Chemicals: Synthetic organic compounds, introduced through various human activities, can contaminate drinking water. These include pesticides, food additives, detergents, pharmaceuticals, synthetic fibers, plastics, solvents, and volatile organic compounds, many of which pose serious public health hazards (Dai *et al.,* 2019; Peivasteh-Roudsari*et al.,* 2023).

Inorganic Pollutants: Inorganic contaminants such as mineral acids, trace metals, salts, cyanides, and sulfates, often stemming from human activities, persist in the environment and can be toxic to ecosystems and humans. Some of these pollutants also occur naturally and contribute to groundwater pollution (Jain *et al.,* 2023).

Thermal Pollution: Thermal pollution refers to the increase in water temperature caused by industrial discharges, particularly from power plants and manufacturing facilities. Elevated temperatures reduce dissolved oxygen levels, negatively impacting aquatic life and disrupting ecosystem balance by altering metabolic and enzymatic activities of aquatic organisms (Jiménez &NashBraun, 2023; Kolawole&Iyiola, 2023).

Toxic Metals: Toxic metals such as arsenic, cadmium, chromium, lead, mercury, and others pose severe health risks, including neurological disorders, cancers, and immune dysfunctions.

These metals enter water supplies through natural geological processes, corrosion of pipes, industrial discharges, and waste leaks (Chao *et al.,* 2023; Numbere*et al.,* 2023).

2.4. Physical Parameters of Drinking Water Quality

Several physical parameters such as turbidity, temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), and total suspended solids (TSS) influence the chemical and biological characteristics of drinking water (Atumo*et al.,* 2023).

2.4.1 Turbidity

Turbidity refers to the cloudiness or haziness of water caused by suspended particles, including plankton, clay, silt, finely divided organic and inorganic matter, soluble colored compounds, and microorganisms (Alfina*et al.,* 2023). It is an optical property that scatters and absorbs light. Turbidity affects consumer acceptance and plays a critical role in selecting and evaluating water treatment methods (Juncosa*et al.,* 2022). High turbidity reduces the effectiveness of chlorine disinfection by shielding microorganisms and can even promote microbial growth. Thus, disinfection processes require low turbidity levels, ideally below 1 NTU, to be effective (Maiyo*et al.,* 2023).

2.4.2 Temperature

Water temperature impacts the solubility and perception of various inorganic and chemical substances; generally, colder water is preferred for taste (Yamanaka *et al.,* 2017). Elevated temperatures encourage microbial growth and can exacerbate issues with taste, odor, coloration, and corrosion (Gamawa&Okpanachi, 2023). Temperature governs biochemical and biological processes such as microbial growth, decay, and mineralization by influencing gas solubility. Water temperatures exceeding 27°C, often due to effluent pollution, reduce dissolved oxygen and render water unsuitable for drinking (Agudelo-Vera *et al.,* 2020).

2.4.3 Electrical Conductivity (EC)

Electrical conductivity measures water's ability to conduct an electric current, primarily influenced by dissolved inorganic ions (Moussaoui *et al.,* 2023). Organic compounds generally contribute little to conductivity due to poor ionization. Changes in conductivity can indicate contamination from discharges or pollutants. Conductivity is measured using specialized sensors, with values influenced by temperature and pH as water ionizes. For example, dissolved carbon dioxide forms ions that alter both conductivity and pH. The Ethiopian Central Statistical Agency categorizes EC levels as low (<150 µS/cm), moderate (150–500 µS/cm), high (500–800 µS/cm), and very high (>800 µS/cm) (Pal *et al.,* 2015).

2.4.4 Total Dissolved Solids (TDS)

TDS consists mainly of inorganic salts dissolved in water, such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates (Maliki *et al.*,2020; Ängesleväet *al.,* 2023). TDS measurements generally consider solids small enough to pass through a filter with pores no larger than 2 micrometers. The concentration of TDS depends on geological formations, climate, and groundwater residence time (Imam, 2023). The maximum allowable TDS concentration in drinking water is 1500 mg/L (Avutu*et al.,* 2023). High TDS affects water's physical and chemical properties, visual clarity, gas solubility, and suitability for agricultural, industrial, and domestic use. Levels above 1200 mg/L can be unappealing to consumers and pose risks for individuals requiring low-sodium intake, such as those with hypertension or diabetes. Additionally, high TDS can interact with heavy metals, reducing water transparency and inhibiting photosynthesis.

2.4.5 Total Suspended Solids (TSS)

TSS refers to particles, including minerals and organic matter that do not pass through a filter of 1.2 micrometers. These suspended solids influence water clarity and quality. Increased sediment levels reduce water transparency and may enter groundwater through runoff from industrial, urban, or agricultural sources, thereby degrading water quality (Henrietta *et al.,* 2023).

2.5. Chemical Aspects of Drinking Water Quality Parameters

The chemical composition of drinking water plays a vital role in determining its suitability for domestic, commercial, and agricultural use. Assessing chemical quality involves considering factors such as the reliability of distribution systems, protection of water sources, and effectiveness of treatment processes (WHO, 2017).

2.5.1 pH of Pure Water

pH measures the acidity or alkalinity of a solution based on the concentration of hydrogen and hydroxide ions, typically ranging from 0 to 14. A pH of 7 is neutral, values below 7 are acidic, and those above 7 are basic. Drinking water generally has a pH between 6 and 8.5. Water with low pH values may be corrosive and hazardous, whereas water with high pH can have a bitter taste. According to WHO guidelines, the acceptable pH range for drinking water is 6.5 to 8.5. It is also important to monitor pH alongside residual chlorine levels, as pH affects the efficiency of chlorine disinfection (Yehia*et al.,* 2021).

2.5.2 Total Alkalinity (TA)

Total alkalinity refers to the water's capacity to neutralize acids and resist pH changes, mainly due to the presence of bicarbonates formed when water interacts with certain minerals in soil and rock. This buffering capacity is important for maintaining stable water quality, especially as drinking water sources can be affected by acidic inputs such as wastewater and acid rain (WHO, 2017).

2.5.3 Total Hardness (TH)

Water hardness is primarily caused by calcium and magnesium ions and is often indicated by the formation of soap scum and increased soap consumption. The perception of water hardness varies among communities, but generally, hard water raises boiling points and reduces soap’s ability to lather. (Shariati-Rad and Heidari2020) provide a classification of water hardness levels, summarized in Table 2.

Table 1. Classification of Water Based on Total Hardness

No.	Total Hardness (mg/L)	Nature of Water
1	0 – 60	Soft
2	61 – 120	Moderate
3	121 – 180	Hard
4	>181	Very Hard

2.5.4 Fluorides (F^-)

Fluorine, abundant in the Earth's crust, occurs in minerals such as fluorspar, cryolite, and fluorapatite. While fluoride is naturally present in many water sources, higher concentrations are commonly found in groundwater, especially in areas rich in fluoride-containing minerals. Some wells may contain fluoride levels up to 10 mg/L or more. Regions with elevated fluoride include parts of South America, Central America, China, and India (WHO, 2017). The weathering of rocks and soil contributes to fluoride presence in water. Excess fluoride intake leads to fluorosis, a health condition caused by prolonged consumption of high fluoride levels. The maximum permissible fluoride concentration in Ethiopian drinking water, aligned with WHO guidelines, is 1.5 mg/L. Fluoride concentrations above this threshold can cause dental fluorosis, while levels between 0.6 and 1 mg/L provide beneficial protection against tooth decay, particularly in children (WHO, 2023).

2.5.5 Chloride (Cl^-)

Surface waters generally have lower chloride levels than groundwater. Chloride is vital for metabolic and physiological functions in the human body. However, elevated chloride levels can corrode pipes, damage infrastructure, and adversely affect plant growth. According to WHO, chloride concentrations in drinking water should not exceed 250 mg/L. At this level, water may develop a salty taste, and individuals accustomed to high chloride levels may experience laxative effects. High chloride concentrations can also indicate sewage contamination (Meride&Ayenew, 2016).

2.5.6 Magnesium (Mg2+)

Magnesium is a naturally occurring element essential for living organisms and ranks as the eighth most abundant element in the Earth's crust. It is found in minerals like magnetite and dolomite and is critical for human health, with about 25 grams present in the body, mostly in muscles and bones. The WHO recommends a maximum magnesium concentration of 50 mg/L in drinking water (Potasznik&Szymczyk, 2015).

2.5.7 Nitrate (NO_3^-)

Nitrate contamination poses significant health risks, particularly to infants who may develop methemoglobinemia, commonly known as "blue baby syndrome." Sources of nitrate include the nitrogen cycle, industrial discharges, and nitrogen-based fertilizers. Nitrate leaches into both surface and groundwater. While nitrate itself is not highly toxic, its conversion to nitrite can interfere with blood oxygen transport. Surface water typically contains less than 1 mg/L nitrate, but levels above the EPA's recommended limit of 10 mg/L can cause health issues such as stomach disturbances (Meride&Ayenew, 2016).

2.5.8 Sulfate (SO_4^{2-})

Sulfate commonly originates from the dissolution of sulfur-containing minerals such as gypsum and is present in most natural waters. Concentrations increase due to sewage discharge, industrial waste, mine drainage, and pyrite oxidation. Though sulfate is abundant, it generally does not cause significant human health effects. The WHO standard limits sulfate in drinking water to 250 mg/L (Meride&Ayenew, 2016).

2.5.9 Phosphate (PO_4^{3-})

Phosphate enters water bodies primarily through agricultural runoff containing fertilizers, as well as industrial and sewage effluents rich in phosphate-based detergents. Phosphate levels in spring water are usually minimal unless contaminated. As an essential nutrient for algae, high phosphate concentrations contribute significantly to eutrophication in lakes and reservoirs, indicating pollution. Although phosphates are only harmful to humans or animals at very high concentrations, excessive phosphorus can cause digestive problems (Amanial, 2016; WHO, 2023).

2.6 Microbial Quality of Drinking Water

Securing the microbial safety of drinking-water supplies is based on the use of multiple barriers, from catchment to consumer, to prevent the contamination of drinking water or to reduce contamination to levels not injurious to health (WHO, 2011). The majorities of these pathogens derives from human or animal faeces, and are transmitted through the faecaloral route. Although both animal and human faeces are threats to human health and human faeces are generally the most dangerous (UNICEF, 2008). As WHO (2008), recommends failure to ensure drinking-water safety may expose the community to the risk of outbreaks of intestinal and other infectious diseases.

Water sources harbor a wide variety of microorganisms, some harmful and others benign (Almeida *et al.,* 2023). While some non-pathogenic bacteria may cause unpleasant tastes or odors signaling potential water quality issues, the primary concern is the presence of pathogenic microorganisms. These pathogens comprising bacteria, helminths, protozoa, fungi, and viruses mostly originate from human fecal contamination. Microbiological water quality is typically assessed using indicator organisms, mainly bacteria such as thermotolerant (fecal) coliforms and Escherichia coli. Total coliforms, a broader group including thermotolerant coliforms, are also used as bacteriological quality indicators (Lin, 2014).

Microbial contamination data should be interpreted according to local conditions, with thermotolerant coliform bacteria or E. coli counts preferred for bacteriological classification in non-chlorinated community water sources, since total coliforms may persist with minimal hygiene impact (Nabeela*et al.,* 2023).

2.6.1 Total Coliforms

Testing drinking water for total coliforms is a critical safety step prior to consumption (Logan, 2023). Total coliforms include bacteria found in soil, surface runoff, and fecal matter from humans or animals. These bacteria are typically gram-negative, oxidase-negative, rod-shaped, non-spore forming, and capable of fermenting lactose at 35–37°C with gas production within 24–48 hours (Assessing Microbial Safety of Drinking Water, 2002).

2.6.2 Fecal Coliforms

The term “fecal coliform” is often used interchangeably with “thermotolerant coliforms,” which are total coliform bacteria that can ferment lactose at elevated temperatures (44–45°C). These bacteria predominantly originate from the intestines of warm-blooded animals and are a key indicator of fecal contamination in water (King & Leonard, 2023).

2.7 Measurement of Bacteriological Parameters (Microbial Analysis)

According to (Zulu *et al.*2023), bacterial contamination in water samples is commonly analyzed using the membrane filtration method. The membrane filtration method involves filtering 100 mL of water through a 0.45 µm pore-size membrane, retaining microorganisms on its surface. The membrane is then incubated on culture media at 44.5°C for 24 hours to suppress non-fecal bacteria and promote the growth of thermotolerant species. Colonies formed are counted to determine microbial density.

Further identification of bacteria is performed using tests such as the Indole Production Test, which detects the breakdown of tryptophan by bacteria such as E. coli, Proteus species, Morganellamorganii, and Providencia. A positive result is indicated by a red layer after adding Kovac’s reagent, signifying indole production (Ogochukwu*et al.*, 2023).

2.8 WHO and Ethiopian Standards of Drinking Water Quality

Water safety gained international attention after the 1972 United Nations Conference on the Human Environment in Stockholm (Greve, 2023). The WHO Guidelines for Drinking Water Quality (GDWQ) emphasize the implementation of Water Safety Plans (WSPs) to protect public

health effectively (Perveen, 2023). Table 3 integrates the physicochemical and microbiological parameter limits as established by the Ethiopian Central Standards (CES) and WHO standards.

Table 2.Physicochemical and Microbiological Parameter Guideline Values for Quality of Drinking water.

No	Parameter	WHO Standard	Ethiopian Standard (ES)
1	Turbidity (NTU)	< 5	< 5
2	Temperature (°C)	< 15 °C	< 15 °C
3	Electrical Conductivity (µS/cm)	1000	1500
4	Total Dissolved Solids (mg/L)	1000	1000
5	Total Suspended Solids (mg/L)	-	-
6	pH	6.5 - 8.5	6.5 - 8.5
7	Total Alkalinity (mg/L)	300	200
8	Total Hardness (mg/L)	300	300
9	Chloride (mg/L)	250	250
10	Fluorides (mg/L)	1.5	1.5
11	Nitrate (mg/L)	50	50
12	Sulphate (mg/L)	< 250	250
13	Phosphate (mg/L)	5	-
14	Total Coliform (cfu/100mL)	-	-
15	Fecal Coliform (cfu/100mL)	-	-

3. MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted in Amuru Town, located in the Horro GudurruWallaga Zone of the Oromia Regional State, Ethiopia. Oromia is the largest regional state in Ethiopia in terms of

geographical coverage, and Horro Gudurru Wallaga is one of its administrative zones.Amuru Town is situated approximately 68 km from Shambu, the administrative capital of Horro Gudurru Wallaga Zone, and about 408 km from Addis Ababa, the capital city of Ethiopia. Geographically, the town lies at 9°58′59″ N latitude and 36°58′58″E longitude.Administratively, Amuru Town is bounded by Makano Kebele to the east, Ejere Goromti to the south, Haro Walo Kebele to the north, and Nafiro Kebele to the west. According to the most recent statistical report obtained from the Woreda Administrative Office, the total population of Amuru Town was 6568. The geographic location and administrative structure of Amuru Town provided an appropriate setting for conducting the present study.

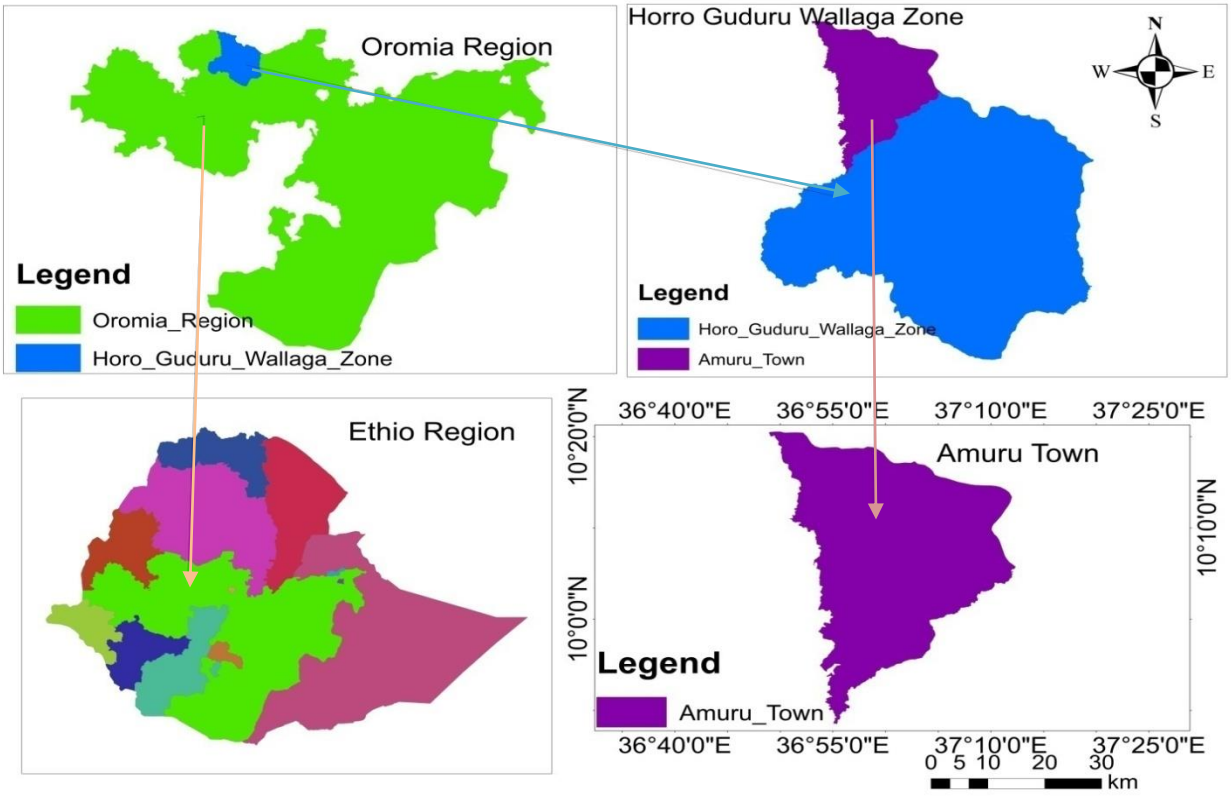


Figure 1. Location Map of the study Area

3.2 Chemicals and Reagents

All chemicals and reagents used in this investigation were of analytical reagent grade. The reagents included ethylenediaminetetraacetic acid (EDTA, 98%), potassium chloride (KCl, 99.5%), buffer tablets (pH 4.0, 7.0, and 9.2), Eriochrome Black T (95%), ammonia buffer (NH_3 buffer), phenolphthalein (indicator), methyl orange (indicator), sulfuric acid (H_2SO_4, 98%),

silver nitrate ($AgNO_3$, 98%), and potassium chromate (K_2CrO_4, 95%). In addition, distilled water was used for sample preparation and for cleaning laboratory glassware and equipment prior to analysis throughout the experimental procedures.

3.3 Instruments and Apparatus

A microprocessor-based conductivity/total dissolved solids (TDS) meter was used to measure electrical conductivity (EC) and TDS. Turbidity was determined using a turbidity meter. Water temperature was measured using a laboratory thermometer with a measurement range of 0–100°C. A portable spectrophotometer (Hach Company, Model 59400-45, USA) was used to determine the concentrations of sulfate (SO_4^{2-}), nitrate (NO_3^-), phosphate (PO_4^{3-}), and magnesium (Mg^{2+}). Additional laboratory apparatus included burettes, measuring cylinders, conical flasks, pipettes, and volumetric flasks of various capacities. An analytical balance was used for precise mass measurements. A drying oven, evaporating dishes, and a desiccator were also used during sample preparation and analysis procedures.

3.4 Sample Collection and Preservation

Water samples were collected and preserved in agreement with the World Health Organization's guidelines for drinking water quality assessment (WHO, 2017). A composite sampling technique was employed to obtain representative samples from selected sources. Samples were collected in June 2023 from three different sources: a borehole (point source), a reservoir and a household supply. The samples were coded as SC, R, and Samples were collected from house hold by using systematic random method from 300 houses I took 10 houses 1L by using composite sampling techniques. Each sample was collected in a clean, dry 3L polyethylene bottle. Properly prepared labels were affixed to each bottle to ensure accurate identification. To preserve the samples for physicochemical analysis, 1 mL of concentrated nitric acids was added immediately to each bottle, following recommended preservation procedures (Zhang *et al.,* 2023). The samples were transported aseptically in sterilized, labeled glass containers and kept in an ice box to maintain low temperature during transit to the Department of Chemistry, Wallaga University, for laboratory analysis.Upon arrival at the laboratory, the samples were tightly sealed and stored in a refrigerator at or below 4°C until complete analysis was conducted using standard analytical methods (Cobbina*et al.,* 2015).

3.5 Experimental Site and Period

Sensitive water quality parameters, including temperature and pH, were measured *in situ* at the sampling sites using a thermometer and a portable pH meter, respectively. Laboratory analyses of selected physicochemical parameters such as chloride ion (Cl^-), hardness, total suspended solids (TSS), electrical conductivity (EC), and total dissolved solids (TDS) were conducted using standard titrimetric and analytical steps at Chemistry Laboratory of Wallaga University. Additional physicochemical parameters, including turbidity, fluoride (F^-), nitrate (NO_3^-), sulfate (SO_4^{2-}), phosphate (PO_4^{3-}), magnesium (Mg^{2+}), and calcium (Ca^{2+}), were analyzed at Nekemte City Water Supply and Sanitation Laboratory. Bacteriological analyses, specifically fecal coliform and total coliform counts, were performed at the Nekemte Public Health Research and Referral Laboratory using standard microbiological techniques. The study was conducted over a period of nine months, from June 2023 - march 2024.

3.6 Analysis of Physicochemical and Bacteriological Parameters

All physicochemical parameters were analyzed as soon as possible after sample collection to minimize potential alterations in water quality. Bacteriological analyses were conducted within 6–8 hr of sample collection to prevent microbial proliferation or die-off. The analytical methods used for selected physicochemical and bacteriological parameters are summarized in Table 4.

3.6.1Turbidity

Turbidity was measured using a turbidity meter in accordance with internationally recognized standard procedures. Each water sample was poured into a clean sample cell and allowed to stand briefly to eliminate air bubbles and stabilize the reading. Once the displayed value became stable, the turbidity reading was recorded in nephelometric turbidity units (NTU) (Mankovsky&Mankovskaya, 2023).

3.6.2 Temperature

Water temperature was measured using a calibrated thermometer with a range of 0°C to 100°C. The thermometer was immersed directly into the water sample and left in place for

approximately 3 min until the liquid column stabilized. The temperature reading was then recorded. The procedure followed the method described by(Meride and Ayenew ,2016).

Table 3. Methods of Determining Selected Physicochemical and Bacteriological Parameters

S. No.	Parameter	Method
1	Turbidity	turbidity meter (nephelometric method)
2	Temperature	Measured using a mercury thermometer
3	Electrical Conductivity (EC)	microprocessor-based conductivity/TDS meter
4	Total Dissolved Solids (TDS)	microprocessor-based conductivity/TDS meter
5	Total Suspended Solids (TSS)	Determined by filtration method
6	P^H	portable pH meter (electrometric method)
7	Total Alkalinity	Determined by titration method
8	Total Hardness	Determined by EDTA titrimetric method
9	Fluoride (F^-)	Determined by ion-selective electrode method
10	Chloride (Cl^-)	Determined by argentometric titration method
11	Magnesium (Mg^{2+})	Determined by spectrophotometric method
12	Nitrate (NO_3^-)	Determined by spectrophotometric method
13	Sulfate (SO_4^{2-})	Determined by spectrophotometric method
14	Phosphate (PO_4^{3-})	Determined by spectrophotometric method
15	Total Coliforms and Fecal Coliforms	Determined by membrane filtration method

3.6.3 Electrical Conductivity (EC)

Electrical conductivity (EC) is the property of a solution that indicates its ability to conduct an electric current. Prior to measurement, the conductivity probe was rinsed with deionized water to remove impurities, and the quality of the rinse water was evaluated. The probe was calibrated using a 0.01 M KCl solution. For measurement, the probe was immersed in a beaker containing

the water sample and gently moved up and down to remove any air bubbles from the electrodes. The conductivity value for each sample was then recorded (Shrestha *et al.,* 2017).

3.6.4 Total Dissolved Solids (TDS)

Total dissolved solids were measured after thoroughly mixing the water sample and vacuum-filtering it using a membrane filter. A 100 ml portion of the filtrate was then placed in a conical flask, and TDS was determined using a microprocessor-based TDS meter (Rusydi, 2018).

3.6.5 Total Suspended Solids (TSS)

Total suspended solids were determined using the filtration method in accordance with standard procedures (APHA, 1999; Ma et al., 2020). A 100 mL aliquot of the water sample was placed onto a pre-weighed filter paper before vacuum filtration. After filtration, the filter was removed, and the retained solids were dried in an aluminum dish at 110°C for two hours. The TSS concentration was then calculated as the increase in filter mass per volume of filtered sample and expressed in milligrams per liter (mg/l).

3.6.6 pH

The pH of the water samples was measured using a calibrated portable pH meter. The instrument was calibrated with standard buffer solutions at pH 4.0, 7.0, and 9.0 prior to analysis. A 50 mL portion of each water sample was used for measurement. The pH probe was immersed in the sample until a stable reading was obtained. After each measurement, the probe was rinsed with deionized water to prevent cross-contamination between samples (Rahmanian *et al.,* 2015).

3.6.7 Total Alkalinity

Alkalinity, which stabilizes pH, is primarily composed of carbonate ions and bicarbonate ions. Alkalinity, along with pH and hardness, influences the toxicity of certain substances. Total alkalinity was determined by titrating a known volume of water sample with 0.02M H_2SO_4 in the presence of methyl orange and phenolphthalein indicators (Somridhive& Boyd, 2016). The total alkalinity was calculated using the equation:

$$\text{Total Alkalinity (mg/L as } CaCO_3) = \frac{AxNx50x1000}{vsample} \quad (1)$$

Where: A = volume of standard acid used (mL), N = normality of standard acid, Vsample = volume of water sample (mL)

3.6.8 Total Hardness (TH)

Total hardness was determined using the EDTA titration method. A 20 ml aliquot of each water sample was pipetted into a clean conical flask. Five milliliters of ammonia buffer solution and three drops of Eriochrome Black T indicator were added. The sample was titrated with a pre-standardized EDTA solution until a color change to sky blue indicated the endpoint. Total hardness was then calculated in mg/L as $CaCO_3$ using the formula:

$$\text{TH (in mg/L as } CaCO_3) = \frac{\text{VxNx50x1000}}{\text{vsample}} \qquad (2)$$

Where:N = normality of EDTA solution, V sample = volume of water sample (mL) (Barrie *et al.*, 2023)

3.6.9 Fluoride

Fluoride (F^-) was measured using the ion-selective electrode method. A 25 mL portion of the water sample was mixed with 25 ml of total ionic strength adjustment buffer (TISAB). The mixture was stirred, and a magnetic stirrer was added. After 5 minutes of equilibration, the potential of the electrode was measured. Standard solutions were used to generate a calibration curve, and each sample was analyzed in triplicate (Thiruppathi *et al.*, 2023).

3.6.10 Chloride

Chloride ions content was determined using argentometric titration. Ten milliliters of water sample was placed in a conical flask, and three drops of potassium chromate indicator were added. The sample was titrated with 0.02 M silver nitrate (until a brick-red endpoint appeared. A blank titration was carried out using distilled water. Chloride concentration was calculated as:

$$\text{Chloride ion concentration (mg/L)} = \frac{(V1-V2)\text{xNx35.5x1000}}{\text{V sample}} \qquad (3)$$

Where:V1= volume of $AgNO_3$ for sample, V2= volume of $AgNO_3$ for blank, N = normality of $AgNO_3$, Vsample= sample volume (mL) (Sun *et al.*, 2023)

3.6.1 Magnesium

Magnesium (Mg^{2+}) content was determined using a spectrophotometric method. A 20 mL aliquot of each water sample was prepared and analyzed according to APHA standard procedures (APHA, 1999).

3.6.12 Nitrate

Nitrate (NO_3^-) was measured using UV spectrophotometry. Fifty milliliters of filtered water sample were mixed with 1 mL of HCl. Calibration standards were prepared in the range 0–7 mg/L NO_3^-. Absorbance was measured at 220 nm (nitrate) and 275 nm (interference from dissolved organic matter) (Lal*et al.,* 2023).

3.6.13 Sulfate

Sulfate (SO_4^{2-}) was determined spectrophotometrically. Twenty milliliters of water sample were mixed with 1 mL of HCl and 1 mL of conditioning reagent, stirred for 30 s, and allowed to react for 10 minutes. Absorbance was measured according to APHA guidelines (1999).

3.6.14 Phosphate

Using a spectophotometricapproach,the phosphate(PO_4^{3-})content of water sample was detrmined. Water samples were filtered through Whatman filter paper, and 20 mL of the filtrate was analyzed following (Ganesh *et al.*,2012).

3.7. Bacteriological Analysis

Total coliform and fecal coliform counts were determined using the membrane filtration method (APHA, 1999). Sterile absorbent pads were placed in Petri plates and soaked with Lauryl Sulfate Broth. A 100 mL water sample was filtered through a 0.45 µm membrane. The filter was then placed on the prepared pad. Plates were pre-incubated at 37°C for 4 hours to recover stressed coliforms and then incubated at 37°C (total coliform) and 44°C (fecal coliform) for 24 hours. Colonies were counted and recorded (Adesakin*et al.,* 2020).

$$\frac{\text{number of colonies}}{100\ \text{mL}} = \frac{\text{coliform colonies counted}}{\text{mL sample filtered}} \times 100 \qquad (4)$$

3.8. Data Analysis

Data were organized and summarized using Microsoft Excel 2010. Statistical analyses, including descriptive statistics, one-way analysis of variance (ANOVA), and Pearson correlation, were performed using SPSS version 16. Results were interpreted in accordance with standard significance thresholds.

4. RESULTS AND DISCUSSIONS

4.1. Physicochemical Parameter Analysis

Table 4 presents the analysis of the physicochemical properties of water collected from the source (SC), reservoir (R) and household (HH). A total of 14 physicochemical parameters were analyzed, including fluoride, chloride, magnesium, nitrate, sulfate, phosphate, temperature, electrical conductivity, total dissolved solids, total suspended solids , pH, total alkalinity, and total hardness. The results are discussed in the following order.

4.1.1. Turbidity

Turbidity, an indicator of particulate pollution, affects the potability of water. In this study, the mean turbidity values were:1.523 ± 0.137 NTU (SC), 1.433 ± 0.152 NTU (R) and1.933 ± 0.152 NTU(HH)**.** Statistical analysis indicated that turbidity differed significantly among the water sources ($P < 0.05$). All measured values were below the maximum permissible limit of 5 NTU as recommended by the Ethiopian Standards (ES) and World Health Organization (WHO, 2017). The highest turbidity observed in household samples (HH) may be due to the presence of organic suspended matter.When compared with other studies in Ethiopia, the turbidity values in Amuru Town were relatively low (Sitotaw*et al.,* 2021; Furgassa, 2016; Eliku&Sulaiman, 2015) and were comparable to findings reported by Duressa*et al.* (2019). Based on these results, all water sources can be considered safe for drinking with respect to turbidity.

4.1.2. Temperature

Table 4 displays the temperature results of the drinking water samples that were collected, tested, and tabulated. Table 5 displays the mean water temperatures were as follows: 17.666 ± 0.577°C (SC), 17.066 ± 0.105°C(R) and 17.600 ± 0.100°C (HH)**.**All sampled locations recorded temperatures above the ES and WHO recommended limit of 15°C. The higher temperature observed at SC may be attributed to direct exposure to sunlight and the relatively warmer microclimate of the source area. Statistical analysis revealed significant differences in temperature among the water sources ($P \leq 0.05$). The observed temperature values are consist with those reported in Wegeda Town by Sitotaw*et al.* (2021), suggesting similar climatic and environmental influences on drinking water quality in these regions.

Table 4. Mean Values of Physicochemical Parameters along the drinking Water Samples

Parameters	Sample sites			Standards		ANOVA Results		
	SC	R	HH	ES	WHO	LSP	P-Value	Significance ($P \leq 0.05$)
Turbidity (NTU)	1.523 ±0.137	1.433±0.152	1.933±0.152	<5	<5	0.005	0.009	Significant
T (^{o}C)	17.666±0.577	17.066±0.105	17.600±0.100	<15	<15 ^{o}C	0.077	0.143	Insignificant
EC (µs/cm)	60.6±0.01	59.9±0.030	60.8±0.17	1500	1000	0609	0.855	insignificant
TDS(mg/L)	39.16±0.026	20.20±0.026	29.50±0.011	1000	1000	0.000	0.000	Significant

TSS (mg/L)	0.125±0.003	0.240±0.002	0.401±0.006	-	-	0.000	0.000	Significant
pH units	5.143±0.083	4.85±0.000	4.86±0.000	6.5-8.5	6.5-8.5	0.000	0.000473	Significant
TA (mg/L)	23.06±0.333	31.36±0.122	13.40±0.010	200	300	0.001	0.000	Significant
TH (mg/L)	10.50±0.201	2.46±0.057	0.46±0.057	300	300	0.004	0.008504	Significant
F^- (mg/L)	BDL	0.3567±0.050	0.40±0.010	1.5	1.5	0.002	10	Significant
Cl^- (mg/L)	0.70±0.026	0.46±0.057	0.46±0.057	250	250	0.124	0.199941	insignificant
Mg (mg/L)	1.17±0.435	1.60±0.416	1.43±472	50	50	0.003	0.000	significant
NO_3^- (mg/L)	2.80±0.100	1.30±0.100	1.20±0.100	50	50	0.000	0.000	Significant
SO_4^{2-} (mg/L)	1.0±0.000	2.0±0.000	1.0±0.000	250	< 250	-	0.08	-
PO_4^{3-} (mg/L)	0.40±0.000	0.2±0.000	1.2±0.01	5	-	0.001	0.000	Significant

Note; BDL- below detection limits, SC-Source, R- reservoir, HH-household water sample sites.

4.1.3. Electrical Conductivity (EC)

Electrical conductivity (EC) reflects the type and concentration of dissolved ionic species in water, providing an indicator of overall water quality. The mean EC values, as presented in Table 4, were: 60.6 ± 0.01 µS/cm (SC), 59.9 ± 0.03 µS/cm (R) and 60.8 ± 0.17 µS/cm (HH). All values were well below the permissible limits set by ES (500 µS/cm) and WHO (400 µS/cm).The slightly higher EC at SC may be attributed to local soil composition, agricultural runoff, and geological factors. No statistically significant difference was observed among the water sources ($P \leq 0.05$). EC values in this study were lower than those reported for other Ethiopian cities (Yasin*et al.,* 2015; Meride&Ayenew, 2016).

4.1.4. Total Dissolved Solids (TDS)

TDS serves as a general water quality indicator, affecting both aesthetic properties and water taste. The mean TDS values were: 39.16 ± 0.026 mg/L (SC), 20.20 ± 0.026 mg/L (R) and 29.50 ± 0.011 mg/L (HH) as indicated in Table 4. The highest TDS at SC indicates greater mineralization compared to other sites. All values were well below the WHO and ES limits of 1500 mg/L and 1000 mg/L, respectively. Compared to studies in Mekelle, Arbaminch, East

Wollega, and Jigjiga (*Abera et al.,* 2022; Amanial, 2016; Olika*et al.*, 2022; Netshitanini*et al.,* 2023), these levels were lower. Statistical analysis revealed significant differences among the sites ($P \leq 0.05$).

4.1.5. Total Suspended Solids (TSS)

TSS reflects the concentration of suspended particles, soil, and silt, which affect turbidity (Belay *et al.,* 2023). The mean TSS values were: 0.125 ± 0.003 mg/L (SC), 0.240 ± 0.002 mg/L (R)and 0.401 ± 0.01 mg/L (HH). All sites exhibited low levels of suspended solids, lower than those reported in Arbaminch by Amanial (2015). Statistically significant differences were observed among the sites ($P \leq 0.05$).

4.1.6.pH

A measure of the concentration of hydrogen ions in water and an indicator of its acidity or alkalinity is the pH (Saravanan*et al*., 2023). The measured mean pH values for the drinking water sample sites in the current investigation was 5.143 ± 0.083 (SC), 4.85 ± 0.000 (R), and 4.86 ± 0.000 at HH (Table 5). The water samples that were taken from each sample showed statistically significant mean changes ($P\leq 0.05$). For each of the observed readings, the concentrations are all below the safe limit of 6.5 to 8.5 criteria set by the ES and WHO. It is possible to correlate household and agricultural practices that release acidic substances into the source and depress the pH at the reservoir with drinking water sources that have a pH of less than 5.12. Comparing the results of the identical drinking water samples with the study's sample, the hydrogen power (pH) mean concentration values were lower obtained by Meride&Ayenew (2016) in Wondo Genet Campus, Ethiopia.

4.1.7. Total Alkalinity (TA)

Carbonates and bicarbonates are the main causes of the surface water's alkalinity. The total alkalinity of water samples used in the current study were 23.06±0.333 (SC), 31.36±0.122 (R), and 13.40±0.010 at (HH) respectively. The water samples that were taken from each water sample showed statistically significant mean changes ($P\leq 0.05$). The maximum allowable concentration of alkalinity in drinking water is 200 mg/L, as stated by ES, and 300 mg/L by WHO. Therefore, the total alkalinity content levels in all sample sites in this investigation were

determined to be within the upper limits that the ES and WHO allow. The total alkalinity levels reported by (Haftu&Sathishkumar, 2020; Abdisa&Abebaw, 2014) are higher in various regions of the country than the allowed norms

4.1.8. Total Hardness (TH)

The primary ion that determines hardness is magnesium. In the current investigation, the values of total hardness as $CaCO_3$ varied from 10.50 ± 0.201 mg/L (SC), 2.46±0.057 (R), and 0.46±0.057 (HH) respectively, which were within the acceptable limit and maximum allowable concentrations specified by ES and WHO, respectively. The sampling sites for SC and HH had the greatest and lowest values of total hardness, respectively. Hence, drinking water in part of the study area was soft. In the current study, the recorded mean concentration of total hardness was lower than the result determined at Mizan-Aman town, as reported by (Fikre, 2020), Robe town as reported by (Shigut*et al*., 2017). The statistical analysis showed that there was significant difference at $P \leq 0.05$ between each water sample.

4.1.9. Fluoride (F^-)

The amount of fluoride in drinking water is a major determinant of its brightness. The concentration of fluoride in the study's three sampling locations ranged from BDL (SC), 0.3567±0.050 mg/L (R), and to 0.40 ± 0.010 mg/L (HH) (Table 4). As indicated in (tables 5), the average fluoride level in residential drinking water sites is statistically significant. The result were all under the 1.5 mg/L acceptable ES and WHO standards. This could be as a result of the lack of industrial contamination in the research area and the water's contact with fluoride-rich geological layers, which were the main source of fluoride in drinking water. The present study of drinking water samples were lower than the study reported by (Kanko *et al.,* 2023; Bekele*et al*., 2018) in Ethiopia.

4.1.10. Chloride (Cl^-)

The most prevalent anion in water is often chloride, which gives the liquid a salty flavor. It is mostly produced through the evaporation of seawater, industrial waste, and hydrochloric acid salts such as table salt (NaCl). The total amount of chloride found drinking water samples were 0.70 ±0.026mg/L (SC),0.46±0.057 mg/L (both at R and HH) respectively .The result was within

permissible level given by both ES and WHO, respectively. The statistical analysis showed that there was no significant difference at P≤ 0.05 between each water sample. Higher chloride concentration in samples from source (SC) may be due to big discharge of sewage near the sampling sites. The result was lower than the study conduct in Amhara region, and Addis Ababa by (Kassegne&Leta, 2020) and (Alemu*et al*., 2015) respectively.

4.1.11. Magnesium (Mg^{2+})

According to (tables 4), the mean value of magnesium differs considerably between drinking water house hold locations. 1.17±0.435 mg/L (SC), 1.60±0.416 (R), and 1.43±472 (HH). The result was within permitted amounts of 50 mg/L specified by ES and WHO. Because of the depth at which the water was in touch with the aquifer beneath the rock surface, there was a larger magnesium in drinking water at the source. The measured mean content of magnesium in this study was below study conducted in Robe town, Ethiopia (Shigut*et al*., 2017) and DamotSoreDistrict, Ethiopia (Bekele*et al*., 2018). The results of the statistical analysis indicated that there was a significant difference between each water sample at P < 0.05.

4.1.12. Nitrate (NO_3^-)

The nitrate (NO_3^-) content in drinking water is a critical marker of both the microbiological contamination of the water with organic matter and the accumulation of nitrate from leaching from nearby agricultural regions. In this study, nitrate concentrations ranging from 2.80±0.100 mg/L (SC), 1.30±0.100 mg/L (R), and 1.20±0.100 mg/L (HH), respectively .This might be the case even when the farmers' crops are near groundwater sources and there isn't any excessive nitrate leakage from organic wastes and fertilizers in the nearby fields. The drinking water sites differ significantly from one another (tables 4). Therefore, nitrate measurements of the water sources were much lower than the recommended limits of 50 mg/L in drinking water set by both WHO and ES. The nitrate mean concentration values of drinking water samples in the current study were lower than reported by (Abera*et al*., 2022), in Mekelle City, Ethiopia, (Kassegne& Leta,2020) in Ankoberdistrict,Ethiopia and closely matched with result determined in Damot Sore by (Bekele*et al*.,2018).

4.1.13. Sulfate (SO_4^{2-})

One of the least toxic anions is sulphate, and it would take a large consumption to have any negative health effects (especially diarrhea-like symptoms). Avoid high quantities since they also harden water (Fernando *et al*., 2018). Drinking water from the sampling areas generally had low SO42- concentrations, ranging from 1.0±0.000 mg/L (SC), 2.0±0.000 mg/Land 1.0±0.000 mg/L (HH) respectively (Table 4). They were all within the ES and WHO acceptable maximum contaminant limits (250 mg/L). Regarding its sulfate concentration, this finding further validates that each water is safe to drink and use for other household purposes. This study's sulfate content was lower than that of previous Ethiopian studies by (Shigut*et al*., 2017; Duressa*et al*., 2019)

4.1.14. Phosphate (PO_4^{3-})

Groundwater may include phosphate due to fertilizer-treated agricultural effluent, detergents, and home wastewater. Phosphate levels in the samples of drinking water used for the study range from 0.40±0.000 mg/L (SC), 0.2±0.000 mg/L (R), and 1.2±0.01 mg/L (HH) respectively. On the entire site, the concentration of phosphate is below the maximum acceptable limit set by the WHO (5 mg/L). Phosphate levels in home water samples were greater than those in source and main distribution tank water samples, suggesting that this ion is contaminated in the supply network (near site). All water samples' phosphate content results corresponded closely with those from a research carried out in a town in Ethiopia(Yasin*et al*.,2015) at Jimma,(Duressa*et al*.,2019) at Nekemte town , Shigut*et al*.,2018) at Robe town. The statistical analysis showed that there was significant difference at $P \leq 0.05$ between each water sample.

4.2. Bacteriological Analysis Results

In the present study, the results indicated that the drinking water samples taken from all water sample in Amuru town had no FCs or TCs (table 6). The mean values and standard deviation of the bacteriological analysis of the water sample are displayed in Table 5.

Table 5. Bacteriological analysis of water samples in CFU/100 mL

S/N	**Parameters**	Sampling sites mean ± standard deviation	**ESA**	**WHO**

		SC	R	HH		
1	Total caliform (Tc)	0	0	0	0	0
2	Feacalcaliform (Fc)	0	0	0	0	0

Studies revealed that there was no faecal material pollution of the drinking water (Berihun *et al., 2023*). Overall, the results of the bacteriological examination indicated that the majority of the drinking water samples studied did not include indicator organisms, making them comply with WHO and Ethiopian drinking water recommendations. Most of the water samples examined in this study had bacterial purity that was inferior to that of studies done in other regions of the nation(Gadiso*et al*.,2020) at Munessa district,(Sitotaw*et al*.,2021) at Wegedatown, and (Eliku&Sulaiman,2015) at Adama town. All of the water samples examined in this study had bacteriological qualities that were safe to drink in terms of TC and FC and that complied with or satisfied national or international standards for drinking water. The result was shown in Figure 1.



A (Total coliform) B (fecal coliform)

Figure 1: showed culture plate no visible bacterial colonies

4.3. Correlation matrix of the physicochemical parameters

The ability of water quality measurements to correlate with one another makes quick water quality monitoring much easier. By using Pearson correlation, the interactions between and within the physicochemical properties of the various water sources were further confirmed. The primary physicochemical characteristics of the drinking water in the research region are shown in a matrix of Pearson correlation coefficients in Table 6. The variables deemed significant are those with a coefficient value (r) greater than 0.050. Significant correlation exists at 0.01 levels.

It shows that there is a high correlation between raising one parameter and increasing another, and vice versa. (Shigut*et al*., 2017). The water quality measures exhibit a substantial positive association ($p < 0.01$), which may indicate that the sources of these ions are the same.

Table 6. Pearson Correlation matrix of physicochemical parameters among household water sample

	Trbd	Temp	EC	TDS	TSS	pH	TA	TH	F^-	Cl^-	Mg	NO_3^-	SO_4^{2-}	PO_4^{3-}
Trbd	1													
Temp	0.557	1												
EC	0.787	0.951	1											
TDS	0.158	0.908	0.733	1										
TSS	0.827	-0.006	0.304	-0.425	1									
pH	-0.319	0.609	0.333	0.885	-0.797	1								
TA	-0.952	-0.784	-0.938	-0.452	-0.616	0.014	1							
TH	-0.517	0.423	0.121	0.764	-0.909	0.976	0.231	1						
F-	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	1					
Cl-	-0.347	0.586	0.305	0.871	-0.814	1.000*	0.044	0.982	.[a]	1				
Mg	-0.049	-0.857	-0.655	-0.994	0.521	-0.931	0.352	-0.829	1.000**	0.920	1			
NO_3^-	-0.398	0.539	0.252	0.843	-0.845	0.996	0.099	0.991	-1.000**	0.998*	-0.896	1		
SO_4^{2-}	-0.639	-0.995	-0.977	-0.0860	-0.096	-0.525	0.843	-0.328	-1.000**	-0.500	0.800	-0.451	1	
PO_4^{3-}	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**	-1.000**	1.000**	.[a]	-1.000**	-1.000**	-1.000**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed)

a. Cannot be computed because at least one of the variables is constant

The analytical results demonstrated a strong, positive correlation between turbidity and T (r=0.557), EC T wit (r=0.787), TDS (r=0.827), TSS (r=0.827), F^-(r=1.000$^{**)}$ and PO_4^{3-} (r=1.000$^{**)}$. Temperature was negatively correlated with TSS (r=-0.006), TA (r=-0.784), Mg(r=-0.857), SO_4^{2-}(r=-0.995).

EC was Positively correlated with TDS(r=0.773), TSS(r=0.304),pH(r=0.33),TH(r=0.121),F^-(r=1.00),Cl^-(r=0.305),NO_3^-(r=0.539) and PO_4^{3-}(r=1.00) and negatively correlated with SO_4^{2-}(r=-0.997),Mg(r=-0.65),TA (r=-0.938),TDS was positively correlated with pH(r=0.885), TH(r=0.764), F^-(1.00),Cl-(0.871),NO_3^-(0.843), PO_4^{3-}(r=1.00) and negatively correlated with (SO_4^{2-}(r=--0.0860),TSS (-0.425), TA(r=-0.452),Mg(r=-0.994),TSS positively correlated with F^-(r=1.00), Mg(r=0.521), PO_4^{3-}(r=1.00) and negatively correlated with TA(r=0.616), TH(r=-0.909),Cl^-(r=-0.814), NO_3^-(r=-0.845), SO_4^{2-}(r=-0.096),pH positively correlated with TA(r=-0.014), TH(r=0.976), F^-(r=1.00),Cl^-(r=1.00), NO_3^-(r=0.996), PO_4^{3-}(r=1.00) and negatively correlated with Mg(r=-0.931),SO_4^{2-}(r=-0.525),TA positively correlated with TH(r=0.231), F^-(r=1.00),Cl^-(r=0.044),Mg(r=0.352),NO_3^-(r=0.099),SO_4^{2-}(r=0.843) and negatively correlated with PO_4^{3-}(r=-1.00),TH positively correlated with F^-(r=1.00), Cl^-(r=0.982), NO_3^-(r=0.991) and negatively correlated with Mg(r=-0.829),SO_4^{2-} (r=-0.328) and PO_4^{3-}(r=-1.00),F^- was positively correlated with PO_4^{3-} (r=1.00) and Mg(r=1.00),Cl^- positively correlated with Mg(r=0.920), NO_3^-(r=0.998),and negatively correlated with SO_4^{2-}(r=-0.500),Mg positively correlated with SO_4^{2-} (r=0.800) and negatively correlated with NO_3^-(r=-0.896) and PO_4^{3-}(r=-1.00) and SO_4^{2-} negatively correlated with PO_4^{3-}(r=1.00)

5. CONCLUSIONS AND RECCOMENDATION

5.1. Conclusions

The study examined the quality of drinking water in Amuru, Oromia, Ethiopia by collecting samples from three points: the source, the reservoir, and Households. All the samples are tested for various physicochemical characteristics (like Turbidity, Temperature, EC, TDS, TSS, pH, TA, TH, F^-, Cl^-, Mg, NO_3^-, SO_4^{2-}, and PO_4^{3-}) as well as bacteriological parameters (total coliform and feacal coliform) using standard procedures.

The results showed that some of the physiochemical parameters were within acceptable limits set by WHO and ES. However, temperature and pH were outside the recommended range. The temperature record was above the WHO limit of <15 ^{0}C for all of the water samples tested and it is attributable to will enhance the growth of microorganisms and may increase problems related to taste, odor, color and corrosion.

For bacteriological quality, all water samples were safe, meaning no harmful bacterial contamination was detected. Total coliform and Faecal Coliform was not detected in the water samples and this indicated the absence of total coliform and faecal contamination in the source, reservoir and Households. Because they met ES and WHO water criteria in terms of their bacteriological purity.

Based on the study's findings, the water in Amuru Town, Oromia, Ethiopia's is generally safe to drink in all physicochemical and bacteriological parameters assessed, but there are small issues with pH and temperature that may need attention.

5.2. Recommendations

The majority of the physicochemical and bacteriological parameters from the current study were examined, however not all of the typical characteristics of the water sample were. Thus the current study forwards the following recommendations.

To evaluate the amounts of dissolved oxygen (DO) and metal ions, such calcium, potassium, and heavy metals, that contribute to the hardness of the water and contaminate waterways, more study on the drinking water in each site is required.

The current investigation was restricted to evaluating the physicochemical and bacteriological characteristics of the water sample from the source to the household in a single month. As a result, a comparable study ought to be carried out in various months and seasons. It can be suggested that regular monitoring of drinking water sources and hygiene promotion programs for quality of drinking water in the study area is needed.

All locations, from the source to the home, require further treatment to bring the pH down to a level that is acceptable. The research served as the foundation for an interested party or group to do additional examination of physicochemical quality parameters and other factors in a standardized laboratory using advanced equipment.

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7. APPENDICES

7.1 Appendix Figures



Appendix Figure 1: Sample collected from the source, reservoir and household



Appendix Figure 2: Researcher during the samples filtration.



Appendix Figure 3: The yellow color formed during the methyl orange titration of the time period.

7.2. Appendix Tables

Appendix Table 1: Mean and SD results of pH, TA, TH, F^-, Cl^- and Mg within Each water sample.

		N	Mean	Std. Deviation
pH	SC	3	5.1433	.08386
	R	3	4.8500	.00000
	HH	3	4.8600	.00000
TA	SC	3	23.0667	1.10604
	R	3	31.3667	2.33524
	HH	3	13.4000	1.21655
TH	SC	3	10.5000	4.65725
	R	3	2.4667	.05774
	HH	3	.4667	.05774
Flouride	SC	3	.0000	.00000
	R	3	.3567	.01528
	HH	3	.4000	.01000
Chloride	SC	3	.7000	.26458
	R	3	.4667	.05774
	HH	3	.4667	.05774
Magnesium	SC	3	1.1700	.04359
	R	3	1.6133	.04163
	HH	3	1.4367	.04726

Appendix Table 2: Mean and SD results of pH, TA, TH, F^-, Cl^-, and Mg within Each water sample.

		N	Mean	Std. Deviation
Nitrate	SC	3	2.8000	.10000
	R	3	1.3000	.10000
	HH	3	1.2000	.10000
Sulphate	SC	3	1.0000	.00000
	R	3	2.0000	.00000
	HH	3	1.0000	.00000
Phosphate	SC	3	.4000	.00000
	R	3	.2000	.00000
	HH	3	.5667	.05774

Appendix Table 3: Mean and SD result of some Physical Parameters of within each water sample.

		N	Mean	Std. Deviation
Turbidity	SC	3	1.5233	.10786
	R	3	1.4333	.15275
	HH	3	1.9333	.15275
Temp	SC	3	17.6667	.57735
	R	3	17.0667	.11547
	HH	3	17.6000	.10000
EC	SC	3	60.6000	3.21403
	R	3	59.9000	1.47986
	HH	3	60.8000	.17321
TDS	SC	3	39.1600	.02646
	R	3	20.2000	.02646
	HH	3	29.5133	.01155
TSS	SC	3	.1250	.00361
	R	3	.2400	.00265
	HH	3	.4010	.00361

Appendix Table 4: ANOVA results of physicochemical parameters of each water sample

ANOVA		
		Sig.
Turbidity	Between Groups	.010
Temperature	Between Groups	.144
EC	Between Groups	.856
TDS	Between Groups	.000
TSS	Between Groups	.000
pH	Between Groups	.000
TA	Between Groups	.000
TH	Between Groups	.009
Fluoride	Between Groups	.000
Chloride	Between Groups	.200
Magnesium	Between Groups	.000
Nitrate	Between Groups	.000
Sulphate	Between Groups	.
Phosphate	Between Groups	.000

Appendix Table 5: Pearson Correlation of among physicochemical parameters of each water samples

		Turbidity	Temp	EC	TDS	TSS	PH	TA
Turbidity	Pearson Correlation	1	.557	.787	.158	.827	-.319	-.952
Temp.	Pearson Correlation	.557	1	.951	.908	-.006	.609	-.784
EC	Pearson Correlation	.787	.951	1	.733	.304	.333	-.938
TDS	Pearson Correlation	.158	.908	.733	1	-.425	.885	-.452
TSS	Pearson Correlation	.827	-.006	.304	-.425	1	-.797	-.616
PH	Pearson Correlation	-.319	.609	.333	.885	-.797	1	.014
TA	Pearson Correlation	-.952	-.784	-.938	-.452	-.616	.014	1
TH	Pearson Correlation	-.517	.423	.121	.764	-.909	.976	.231
Fluoride	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**
chloride	Pearson Correlation	-.347	.586	.305	.871	-.814	1.000*	.044
Magnesium	Pearson Correlation	-.049	-.857	-.655	-.994	.521	-.931	.352
Nitrate	Pearson Correlation	-.398	.539	.252	.843	-.845	.996	.099
sulphate	Pearson Correlation	-.639	-.995	-.977	-.860	-.096	-.525	.843
Phosphate	Pearson Correlation	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**	-1.000**

		TH	Fluoride	chloride	Magnesium	Nitrate
Turbidity	Pearson Correlation	-.517	1.000**	-.347	-.049	-.398
Temperature	Pearson Correlation	.423	1.000**	.586	-.857	.539
EC	Pearson Correlation	.121	1.000**	.305	-.655	.252
TDS	Pearson Correlation	.764	1.000**	.871	-.994	.843
TSS	Pearson Correlation	-.909	1.000**	-.814	.521	-.845
PH	Pearson Correlation	.976	1.000**	1.000*	-.931	.996
TA	Pearson Correlation	.231	-1.000**	.044	.352	.099
TH	Pearson Correlation	1	-1.000**	.982	-.829	.991
Fluoride	Pearson Correlation	-1.000**	1	.[a]	-1.000**	-1.000**
chloride	Pearson Correlation	.982	.[a]	1	-.920	.998*
Magnesium	Pearson Correlation	-.829	-1.000**	-.920	1	-.896
Nitrate	Pearson Correlation	.991	-1.000**	.998*	-.896	1
sulphate	Pearson Correlation	-.328	-1.000**	-.500	.800	-.451
Phosphate	Pearson Correlation	-1.000**	1.000**	.[a]	-1.000**	-1.000**

		sulphate	Phosphate
Turbidity	Pearson Correlation	-.639	1.000**
Temperature	Pearson Correlation	-.995	1.000**
EC	Pearson Correlation	-.977	1.000**
TDS	Pearson Correlation	-.860	1.000**

TSS	Pearson Correlation	-.096	1.000**
PH	Pearson Correlation	-.525	1.000**
TA	Pearson Correlation	.843	-1.000**
TH	Pearson Correlation	-.328	-1.000**
Fluoride	Pearson Correlation	-1.000**	1.000**
chloride	Pearson Correlation	-.500	.[a]
Magnesium	Pearson Correlation	.800	-1.000 **
Nitrate	Pearson Correlation	-.451	-1.000**
sulphate	Pearson Correlation	1	-1.000**
Phosphate	Pearson Correlation	-1.000**	1