



**WALLAGA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
COLLEGE OF NATURAL & COMPUTATIONAL
SCIENCES
DEPARTMENT OF CHEMISTRY**

M.Sc. THESIS:

**DETERMINATION OF THE LEVELS OF SELECTED TOXIC
HEAVY METALS IN STREAM DRINKING WATER IN NONN
O BENJA DISTRICT, JIMMA ZONE, ETHIOPIA**

**By:
Dessalegn Fufa Shiferra**

ADVISOR: Melkamu Biyana (PhD)

**October 2025
Nekemte, Ethiopia**



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A thesis submitted to the School of Graduate Studies, Wallaga University, College of Natural and Computational Sciences, Department of chemistry, in partial Fulfillment of the Requirements for the degree of Masters of Science in Analytical chemistry.

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October 2025
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APPROVAL SHEET FOR SUBMITTING RESEARCH THESIS

As member of the Board of the Final MSc. Thesis open defense, we certify that we have read and evaluated the thesis prepared by **Dessalegn Fufa** under the title “**Determination of the Levels of Selected Toxic Heavy Metals in Stream Drinking water in Nonno Benja district, jimma zone, Ethiopia**” and recommended that the thesis be accepted as fulfilling the thesis requirement for the **Degree of Master of Science in Chemistry (Analytical Chemistry)**.

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Dean of College	Signature	Date

Certification of the final research I hereby certify that all the correction and recommendation suggested by the board of examiners are incorporated in to the final thesis entitled “**Determination of the levels of Selected Toxic Heavy Metals in Stream Drinking water in Nonno Benja district, Jimma zone, Ethiopia**” by Dessalegn Fufa.

Dean of SGS	Signature	Date
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DECLARATION

This is to certify that the thesis entitled Determination of the levels of Selected Toxic Heavy metals in Stream Drinking water in Nonno Benja district, jimma zone, Ethiopia submitted in partial fulfillment of the requirements of Degree of Master of Science in Chemistry, Analytical Chemistry stream by the School of Graduate Studies, Wallaga University through College of Natural and Computational sciences and is a faithful record of original research work carried out by **Dessalegn Fufa** under my guidance and supervision no part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by him from various sources during the course of investigation has been duly acknowledged. Therefore, I recommend that it be accepted as fulfilling the thesis requirements.

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Date

STATEMENT OF THE AUTHOR

I Mr Dessalegn Fufa hereby declare that the thesis entitled “**Determination of the Levels of Selected Toxic Heavy Metals in Stream Drinking Water in Nonno Benja District, Jimma Zone, Ethiopia**” submitted by me the degree of masters in Analytical Chemistry is the result of my original and independent research work carried out under the supervision and guidance of, Melkamu Biyana (PhD) Wallaga University school of graduate studies, Department of Chemistry and it has not yet been submitted for the award of any degree. I understand that any violation of the above will be cause for disciplinary action by the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ACRONYMY AND ABRIVATION

FAAS	Flame Atomic absorption spectroscopy
BIS	Basic Indian Standardss
CES	Compulsory Ethiopian standards
FAO	Food and Agricultural Organization
SAS	Statistical analysis Software
WHO	World Health Organization
USEPA	United state Environmental Protection Agency
SD	Standard Deviation
TDS	Total Dissolved Solid
TSS	Total Suspended Solid
HI	Health Index
HQ	Health Quotient
ILCR	Incremental Life Cancer Risk
CSF	Cancer Slope Factor
ET	Exposure Time
DI	Daily Intake

Abstract

Water safety and quality are fundamental to human development and well-being; we are exposed to it through drinking, bathing, ingestion during domestic use, and eating aquatic plants. This implies that there is urgency in monitoring the quality of ground, surface, and coastal waters to maintain human health. This study investigates the levels of selected toxic heavy metals such as Pb, Cd, and Zn and various physicochemical parameters such as pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), phosphate ion, and nitrate ion in stream drinking water sourced from Nonno Benja district (Laga Hillo, Laga Burkitu, and Laga Bakare) sample sites. Heavy metal concentrations were analyzed using flame atomic absorption spectrophotometry, while physicochemical parameters were measured using standard laboratory techniques. Results indicated that the concentrations of Pb and Cd exceeded the permissible limits set by international guidelines, indicating potential health risks to the local population. Nitrate and phosphate levels were also revealing significant variations across sampling sites, which may be attributed to agricultural runoff and wastewater discharge. This study highlights the urgent need for continuous monitoring and management of water quality in the district to safeguard public health and the environment. Except for the phosphate ion, all some physicochemical parameters are below the permissible limit of the WHO and Ethiopian standard guidelines for drinking water. The concentration of the heavy metals detected by the flame atomic absorption spectrophotometer (FAAS) was in decreasing order as $Pb > Zn > Cd$. This might be due to natural sources (weathering of rocks, volcanic activity, and forest fires or deaths, which release metals from the earth's crust) and anthropogenic sources (excessive use of agrochemicals in the district, industrial waste, and mining operations). However, the results of the health hazard index (HI) show the water from the three streams is safe for drinking, depending on the findings from this research.

Keywords: Toxic metals, drinking water, Nonno Benja, water pollution, non-essential elements, some physico-chemical parameter.

UNIT ONE

INTRODUCTION

1.1. Background of the Study

Water is the most important natural resource known on the earth, and it is mainly used for drinking, which comes from the surfaces and underground sources (NkueNouwezem & Libralato, 2021). Heavy metals naturally exist in the earth's crust at different quantities in all ecosystems and are not naturally eliminated in water systems. Human activity has significantly disrupted the heavy metal balance and biogeochemical cycle in many ecosystems, like water (Kaur & Sharma, 2021). They occur in the aquatic environment naturally or through anthropogenic activities such as industrial wastewater and domestic sewage (Jagaba *et al.*, 2024). Because of their solubility in water and their capacity to form bonds with sediment particles, heavy metals are frequently found in aquatic environments (Bao *et al.*, 2024). They are poisonous and determined in the environment, having the propensity to gradually enter the living organisms and to increase through the food chain.

Heavy metals can go up through the food chain, and their buildup in water and sediments will eventually affect humans and other living things through the aquatic ecosystem (Sonone *et al.*, 2020). The accumulation of heavy metals in humans' bodies causes adverse health problems (Feng *et al.*, 2023). These metals move from the water to the sediments and finally to the biota in an aquatic environment. Some of the heavy metals, like iron (Fe), copper (Cu), cobalt (Co), zinc (Zn), manganese (Mn), and chromium (III) (Cr-III), are essential metals since they are required by the body to perform physiological functions of living tissue and regulate many biochemical processes (Zoroddu *et al.*, 2019). Non-essential metals (cadmium (Cd), mercury (Hg), lead (Pb), titanium (Ti), and arsenic (As)) that are not required by living systems are toxic even in trace amounts (Idowuss, 2022). All metals, whether essential or nonessential, are toxic at higher concentrations and are linked to chronic diseases like renal failure, liver cirrhosis, and brain syndrome (Samanth, 2024).

There are over ten (10) heavy metals such as Pb, Co, Hg, Ti, As, Ni, Zn, Cd, Mn, and Cr that have a particular significance in ecotoxicology since they are highly persistent (Adekanmi,

2021). The levels of metals such as Mn, Zn, and Cr are toxic beyond a certain limit, whereas Pb, Ni, and Cd are toxic even in trace amounts (Uddin *et al.*, 2021). When these heavy metal levels exceed the advised existing levels, which differ depending on the specific element, drinking water toxicity is experienced. These heavy metals, Pb, Zn, and Cd, have the following World Health Organization (WHO) recommended limits: 0.01 mg/L, 3.0 mg/L, and 0.003 mg/L, respectively, for drinking water (Almaliki *et al.*, 2022). Heavy metals such as Pb, Cd, and Zn in drinking water have Ethiopian standards and WHO limits of significant concern. Reduced growth and development, cancer, nervous system damage, and, in severe cases, death are a few of the harmful results. Such incidents call for further investigation using holistic approaches to ensure the quality of water used for consumption.

The phosphate and nitrate ions are essential nutrients that play critical roles in aquatic ecosystems. However, their concentrations in freshwater systems can significantly impact water quality and public health. In natural environments, phosphates primarily originate from the weathering of rocks and minerals, while nitrates typically derive from both natural processes and anthropogenic activities such as agricultural runoff, wastewater discharge, and industrial effluents. The increasing agricultural practices, coupled with urbanization, have led to elevated levels of fertilizers being applied to crops. This practice often results in nutrient runoff into nearby streams, contributing to phosphate ions in stream water. Understanding the current levels of phosphates and nitrates is vital for assessing water quality and implementing effective management strategies. Therefore, this research aimed at investigating levels of Cd, Pb, Zn, and some physicochemical parameters such as pH, temperature, electrical conductivity, total dissolved solids, total suspended solids, phosphate ion, and nitrate ion in stream drinking water in No nno Benja District, Jimma Zone, Oromia region, Ethiopia.

1.2. Statement of Problem

Both natural and man-made factors can contribute to the presence of heavy metals, including Cd, Zn, Pb, and some physicochemical parameters in the environment. The development of both plants and animals depends on the presence of these metals in minute amounts. On the other hand, plant and animal development may be resumed if the concentration of these heavy metals and some physicochemical parameters exceeds the maximum allowable values as determined by several

organizations, including the WHO and Ethiopian, due to malfunctions brought on by the heavy metals and some physicochemical parameters being bioconcentration. Heavy metals such as Cd, Zn, and Pb and physico-chemical parameters such as temperature, pH, EC, TDS, and TSS may exist in an environment through natural and anthropogenic means. The presence of these metals in trace concentrations is of great value both to the animal and plant development. On the contrary, if the concentration of these heavy metals surpasses the maximum accepted amount of the state, clearly several different organizations, such as WHO and Ethiopian Standard, then plant and animal growth may be restarted because malfunctions happened by bio-concentration of the heavy metals and some physicochemical parameters. For instance, high levels of lead in the body can cause a decreased pregnancy rate, ovarian damage, testicular damage, testicular atrophy, cellular degeneration, and irregular estrous cycles, as shown in animal studies (Shi *et al.*, 2024). In many developing nations, including Ethiopia, the danger of water-associated diseases and water quality are major public health problems. This is mostly because most of Ethiopia's districts lack adequate study and subsequent monitoring of water quality criteria. One of these districts is the Nonno Benja District. There is no research report on the determination of the level of heavy metals and some physicochemical parameters in drinking water from the stream sources in the Nonno Benja district and Alga town, the capital town of the district. Thus, the researcher is motivated to identify the levels of chosen heavy metals and some physicochemical parameters in the stream water used for drinking in the mentioned district and their associated health risks analysis.

1.3. Fundamental Research Issues

The research that were led by the following issues:

1. Were the levels of essential and non-essential metals in the spring water used for drinking in the Nonno Benja district safe for drinking?
2. Were the levels of selected heavy metals in drinking water of Nonno Benja District were greater/less the WHO standards and compulsory Ethiopian standards (CES)?
3. Were the levels of selected physicochemical parameter in drinking water were greater or less the WHO and Ethiopian standards?

1.4. Research Objectives

1.4.1. General Objective

The most important objective of this research was to evaluate the physicochemical parameters: temperature, pH, electrical conductivity, total dissolved solids, total suspended solids, phosphate ions, nitrate ions, and the concentration levels of selected heavy metals: lead, cadmium, and zinc in stream drinking water in the Nonno Benja district, Jimma Zone, Ethiopia.

1.4.2. Particular Objective

The particular objectives of this research were to:

- ✓ Evaluate selected physicochemical properties such as pH, temperature, conductivity, dissolved solids, suspended solids, nitrate ions, and phosphate ions in the stream drinking water samples.
- ✓ Assess the level of the heavy metals such as Cd, Pb, and Zn in the stream drinking water in Nonno Benja district, Jimma Zone, Oromia Region, Ethiopia.
- ✓ Compare the levels of the metals Cd, Pb, and Zn and some physicochemical parameters in the three streams of drinking water in three kebeles with the acceptable levels of these metals and some physicochemical parameters for living things stated in the standard references of WHO guidelines and Ethiopian standards.

1.5. Relevance of The study

In this study, some physico-chemical parameters and the levels of chosen heavy metals in drinking water from three selected streams in Nonno Benja District were identified and compared with those recommended by WHO and Ethiopian standards. The finding of this research provides baseline data for the consumers and other concerned bodies and communities in the surroundings to identify which stream had equal value of the level of some physicochemical parameters and the concentration of heavy metals with the WHO and Ethiopian permissible limit and to use the one that was suitable for drinking and other purposes.

1.6. Scope of the study

This study was delimited to the determination of the levels of heavy metals (Cd, Pb, and Zn) and some physicochemical parameters such as pH, temperature, EC, TDS, TSS, phosphate ion, and nitrate ion in three selected natural stream drinking waters, namely Laga Hillo, Laga Burkitu, and Laga Bakare, found in Nonno Benja District, Jimma Zone, Oromia Region, Ethiopia, using FAA S and UV techniques.

UNIT TWO

LITERATURE REVIEW

2.1. Global Water Sources

Water is one of the essentials that support all forms of plant and animal life, and it is generally obtained from two principal natural sources: Surface water, such as freshwater lakes, rivers, and streams, and groundwater, such as borehole water and well water (Raimi *et al.*, 2022). Water has unique chemical properties due to its polarity and hydrogen bonds, which means it is able to dissolve, absorb, adsorb, or suspend many different compounds (Etale *et al.*, 2023). Thus, in nature, water is not pure, as it acquires contaminants from its surroundings and those arising from humans and animals as well as other biological activities (Mukhopadhyay *et al.*, 2022).

2.2 Water's Health Benefits

Water is essential to life. The quality of drinking water has a direct impact on human health. About 25% of the human body is comprised of solid matter, while the remaining 75% is water (Hakam *et al.*, 2024). Therefore, if water is not needed in enough amounts, our body becomes dehydrated, and necessary organs will deteriorate. Water also acts as a remover agent in our body. Humans may not adequately wash away from kidneys and liver or totally and correctly empty their not passing solid and liquid waste if they do not drink enough water. This too stays damaging and poisonous in the body. The great length of poisonous substance sits in the body; a lot of the body takes in the toxin back into the bloodstream. Therefore, the poisonous substance makes the left side of the human body experience poisoning and overinfection. Many scholars recommend drinking water every day and at regular intervals as part of a healthy lifestyle (Hakam *et al.*, 2024). A healthy, sedentary adult should drink at least 1.5 liters of water per day (Intorre *et al.*, 2025). This level of water intake balances water no longer and makes the body properly hydrated. The water you use through food and drinks follows a precise route to reach your cells, of which it is an extremely important component. After arriving in the stomach, water comes to the small intestine, where it is mainly absorbed in the duodenum and jejunum. It

crosses the intestinal mucous membrane into the bloodstream and then into the interstitial tissues to arrive in the cells (Zhang *et al.*, 2024).

Water is an essential component of blood, which travels nutritional elements such as vitamins, minerals, protein components, lipids, and carbohydrates to the cells. Water is important for cells to function properly; it comes into the composition of the cells. As a key player in hydrolysis reactions, water is very essential in the biochemical breakdown of what we eat (proteins, lipids, and carbohydrates) (Zhang *et al.*, 2024). Water is also to be given as a carrier, which helps to carry away waste products through urine. Water has a quantity of heat capacity, which helps resist the changes in body temperature in a hot or a cold environment. Water enables the body to release heat when the environmental temperature is higher than the body temperature; we begin to sweat, and evaporation of water from the skin surface cools down the body very efficiently (Zhang *et al.*, 2024). Water with other not freely flowing molecules forms smooth-moving fluids for joints. It also forms acids in gastric and intestinal airways and mucus secretions in the digestive and respiratory systems, respectively (Moini & Ferdowsi, 2024). To make cellular surfaces, water also acts as an unpleasant absorber during walking or running. This function is especially important for the brain and spinal cord (Fouad *et al.*, 2021). Water quality is evaluated by the physical, chemical, and microbiological properties of water. These water qualities, typically throughout the world, are characterized by wide variability. Therefore, the quality of natural water sources used for different purposes should be established in terms of the specific water-quality parameters that most affect the possible use of water (Banda & Kumarasamy, 2020).

2.3. Heavy Metals

Heavy metals are metallic elements with high atomic weight and density (Fisher *et al.*, 2024). These include the transition metals, some metalloids, lanthanides, and actinides (Zhang *et al.*, 2024). More than 20 metals generally exist in a positively charged form and can bind onto negatively charged organic molecules (Salehi, 2025). Being metal ions, heavy metals cannot be degraded or destroyed; therefore, their stability makes them persistent toxic substances in the environment (Kondakindi *et al.*, 2024). Heavy metals as environmental contaminants can be found

in the air, soil, and water, which pose health hazards to the general public (Ali *et al.*, 2021). They can be transferred from one environment compartment to another (Abbas *et al.*, 2020). Therefore, they often exist in the aquatic environment after being released from the natural or anthropogenic sources (Häder *et al.*, 2020). Often, the free ion of the heavy metals is the most bioavailable form, and its concentration can be used to indicate toxicity (Abbas *et al.*, 2020). Some of the elements, such as Zn and Fe, are extremely important for humans; nevertheless, they possess poisonous effects when they are greater than the tolerance limit. The presence of heavy metals in water as contaminants is an indication of global industrialization attributed to the large scale of inappropriate disposal and untreated wastewater containing heavy metals from anthropogenic sources (Al-Khuzai *et al.*, 2024). Water functions as a medium of transport for pollutants, and they can be damaging to both living organisms and the environment (Singh *et al.*, 2022). Heavy metals can bioaccumulate over a period of time, and the concentrations become apparent and measurable (Wang *et al.*, 2024). Through food chains and trophic levels, heavy metal bioaccumulation within the target organ or tissue of organisms can ultimately threaten human health (Oriakpono & Jaja, 2022).

2.4. Advantageous of Heavy Metals

Some heavy metals are nutritionally extremely important for a healthy life; they are provided to us as trace elements (e.g., Fe, Cu, Mn, and Zn). These elements are usually found naturally in fruits, in foodstuffs and vegetables, and in services finding multivitamin products. Diagnostic medical purposes include direct injection of gallium during radiological imaging, dosing with chromium in parenteral nutrition combinations, and the use of lead as a radiation protector around x-ray equipment. Furthermore, heavy metals are used for industrial purposes such as in the manufacture of batteries, pesticides, alloys, steel, textile dyes, electroplated metal parts, and so forth. Side effects are needed in very small amounts; deficiencies of trace elements happen in diseases, whereas their presence in reasonable amounts, on the other hand, may result in poisoning to human life, interrupting the normal functioning of organs and the central nervous system. Anemia from iron deficiency affects more than half of pregnant women and at least one third of children under five years (Orsango *et al.*, 2021).

In Ethiopia, the Food and Agricultural Organization (FAO) estimate indicates the prevalence of

iron deficiency is 85% among children and 58% among pregnant women, while in Kenya, a similar survey estimated 60% and 70%, respectively (Afata *et al.*, 2023).

2.5. Heavy Metals

Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues (Budi *et al.*, 2024). The causes of poisonings vary between metals; for example, while lead poisoning typically may affect cognitive impairment, abdominal pain, vomiting, and anemia, mercury poisoning may cause not important neuropathy, desquamation, and psychological interrupts. Other factors, such as the chronicity of exposure, may also affect symptoms and clinical presentation. There is, however, considerable overlap between the clinical syndromes associated with heavy metal poisoning, often involving gastrointestinal disturbances, and specific identification of metals is required for diagnosis (Gerhardsson, 2022).

Heavy metals may come to the human body through food, water, air, or absorption through the skin when they are in contact with humans in agriculture and in manufacturing, pharmaceutical, industrial, medicinal plants, or residential settings. Less common routes of exposure are during a radiological procedure, from inappropriate dosing or monitoring, during intravenous (parenteral) nutrition, from a broken thermometer, etc. (Sharma & Sethi, 2021). As a rule, serious toxicity is more likely to result from inhalation or skin contact of dust, fumes, or vapors or materials in the workplace.

2.7. Sources and toxicity of selected heavy metals

2.7.1. Zinc

Zinc (Zn) combines up about 75 ppm of the Earth's crust, making it the 24th most plentiful element with a density of 7.14 g/cm³. Zn is usually found in association with other metals, such as Cu and Pb, in ores and has a low affinity for oxygen. It is better to bond with sulfur and occurs as ores such as sphalerite (ZnS), calamine (ZnCO₃), and zincite (ZnO). Zn forms alloys such as brass and bronze and has been used in the construction of buildings, roofing, and cladding (Zahner, 2020). Other uses of Zn include making circuit boards, photocopiers, and dry cell batteries, and its compounds are used in chemical and pharmaceutical industries such as paints, medicines, and nutritional supplements (Zahner, 2020).

The toxicity of Zn is as a result of excessive absorption, which suppresses copper and iron absorption, while free Zn^{2+} ions in solution are highly toxic to plants, invertebrates, and even fish (Biswas *et al.*, 2025). Zinc salts are intestinal irritants and can cause nausea and abdominal pain (Rahimzadeh *et al.*, 2020). Prolonged exposure to high intakes of Zn results in copper deficiency and subsequent anemia (Zahner, 2020). There is, in addition, a situation called the "zinc shakes" or "zinc chills" that can be influenced by the inhalation of freshly formed Zn oxide formed during the welding of galvanized materials. It has been reported that zinc is able to harm nerve receptors in the nose, which can affect anosmia, and recommended that services should stop using zinc-based intranasal cold products and ordered their removal from store shelves. Drinking water containing Zn at levels above 3 mg/L may not be agreed to by consumers (WHO 2024).

2.7.2. Cadmium

Cadmium (Cd) has an oxidation state of +2 and forms a number of inorganic compounds such as sulfates, chlorides, and acetates, most of which are water soluble (Gunasekaran *et al.*, 2025). Cd is a by-product of the mining and smelting of Pb and Zn and is used in nickel-cadmium batteries and paint pigments (Jagaba *et al.*, 2024). Cd can be found in soils under agriculture from insecticides, fungicides, and sludge and services as fertilizers. Cd and its compounds are very poisonous at all levels and likely to accumulate inside organisms and ecosystems. Cd is bio-persistent, and, once absorbed by an organism, it may accumulate for many years (Shah, 2021). Long-term harm from Cd is caused by renal dysfunction, obstructive lung disease, and lung cancer. Cd may also cause criminality in bone abnormalities such as osteomalacia and osteoporosis. In short, after ingestion, Cd is first transported to the liver, where it binds with many proteins to form complexes. These complexes are transported to the kidneys, ultimately affecting the filtering mechanism (Daehn & Duffield, 2021). This affects the excretion of great-value proteins and sugars, further damaging the kidney function. It takes a very long time for Cd that has dosed in kidneys to be excreted from the human body.

Other achieved health causes associated with Cd toxicity are diarrhea, stomach, vomiting, serious bone fracture, reproductive failure, and even infertility (de CarvalhoMachado & Dinis-Oliveira, 2023). In general, frequent exposure to Cd causes the central nervous system, the

immune system, and psychological behavior and is also suggested in DNA damage or cancer development. Cd toxicity was responsible for the pathogenesis of “itai-itai” disease, a name that comes from the cause of pain screams in the Japanese language due to severe pain in the joints and the spine. The disease arose from the uptake of cadmium in locally reduced rice grown in paddy fields irrigated with Cd-contaminated river water (de CarvalhoMachado & Dinis-Oliveira, 2023).

2.7.3. Lead

Lead (Pb) is an important heavy metal in the Earth, about 14 parts per million by weight or 1 part per million by moles. It does not very often occur in pure form in nature. Lead is usually in the form of ores, mostly with copper, zinc, and silver. The most extant lead mineral is galena, which is lead sulfide (PbS). Other minerals of Pb include lead carbonate (PbCO_3) and lead sulfate (PbSO_4). Pb is usually formed from PbS by heating and processing. Pb has become widely distributed in the environment since it was expected and used by humans for a long time. Natural Pb pollution happens from volcanic explosions and forest fires. It has become widely distributed and mobilized in the environment, and human uptake of this nonessential element has consequently increased. At high levels of human exposure there is damage to almost all organs and organ systems, most essentially the central nervous system, kidneys, and blood, culminating in death at reasonable levels. At low levels, heavy meal synthesis and other biochemical processes are affected, psychological and neurobehavioral functions are impaired, and there is a range of other effects (Rathor & Ch, 2024).

The toxicity of Pb is mostly too gradual in the bones and teeth. This affects brittle bones and weakness in the wrists and fingers. Mobilized Pb can be deposited in the soft tissues of the body and can affect musculoskeletal, renal, ocular, immunological, neurological, reproductive, and developmental effects. Damaged kidney function and a weakened immune system can also result from overexposure to Pb. Various reproductive effects, including decreased pregnancy rate, ovarian damage, testicular damage, testicular atrophy, cellular degeneration, and irregular estrous cycles, have been shown in animal studies (Shi *et al.*, 2024).

2.8. The Guideline of Drinking water

Quality of drinking water, as defined by the guidelines, does not replace any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life progressions. In case of consuming contaminated water, people at greatest risk of waterborne disease are infants and young children, people who are debilitated, and the elderly, especially when living under unsanitary conditions (Adler, 2025). Those who are generally at risk of waterborne illness may need to take additional steps to protect themselves against exposure to waterborne pathogens (WHO, 2024).s

Table 1. Drinking water Guideline values of some physic parameter and heavy metals in mg/L different standards (2024)

Parameter	USEPA	WHO	Ethiopia	BIS
Boron	--	2.4	0.3	1.0
Aluminum	0.05-0.2	NM	0.2	0.2
Arsenic	0.01	0.01	--	0.05
Cadmium	0.005	0.003	0.006	0.003
Copper	1.3	2.0	0.013	1.5
Chromium	0.1	0.05	0.008	0.05
Iron	0.3	0.3	0.243	0.3
Lead	0.015	0.01	0.007	0.01
Mercury	0.002	0.006	--	0.001
Nickel	--	0.02	0.022	0.02
Zinc	5.0	3.0	0.492	15
Manganese	0.05	0.4	0.5	0.3
Nitrate ion	10	50	50	45
Phosphate ion	--	0.03	--	--

NM-- Not mention

2.9 Nitrate ion

High concentrations of in domestic water supplies can be poison to human life. is used highly in inorganic fertilizers. Ammonia, which is oxidized to nitrite, is first made in soil by the

breakdown of fertilizers as part of inorganic nitrogen and waste products, or else organic nitrogen. During growth, plants absorb it and employ it to synthesize organic nitrogenous substances. High concentrations of in surface or groundwater generally show agricultural contamination from fertilizers and manure (**Table 1**) WHO, 2024 guideline. Drinking water permissible limits for nitrate are strict because the nitrates can be decreased to nitrites, which oxidize iron in blood hemoglobin from ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}). The produced compound, called methemoglobinemia, cannot support oxygen. The produced oxygen deficiency is called methemoglobinemia. It is especially toxic in infants (blue baby syndrome) because of their not large total blood volume. A health-based guideline value for nitrate of 50 mg/L (expressed as nitrate ion) was recommended in the WHO Guidelines for drinking water quality to prevent methemoglobinemia (WHO, 2024).

2.10 Phosphate ion

Phosphate is an ion with the chemical formula. It is extremely important for food production and human health. Therefore, large quantities of phosphate have been used in modern daily life and industrial fields (Ruiz-Gonzalez, 2024). However, the excessive amount of phosphate existing in the drinking or environmental water has a negative effect on biological systems and aquatic ecosystems (Hakkim *et al.*, 2024). Moreover, the phosphate level in water can also provide useful information about eutrophication and some other problems (Fernandez-Figueroa *et al.*, 2024). Therefore, sensitive and selective detection of phosphate contaminants in water samples is needed. This ion can exist in several forms depending on the pH of its environment, forming dihydrogen phosphate and hydrogen phosphate ions. The phosphate ion carries a negative three (3-) charge. Phosphate occurs naturally in water sources but can also enter drinking water through human activities like farming and industry (Nadagouda *et al.*, 2024).

UNIT THREE

MATERIALS AND METHOD

3.1. Location of the study Area

The study area was located in the Nonno Benja district, Jimma Zone, Oromia Regional State, Ethiopia. Nonno Benja District was located about 506 km away from Addis Ababa, the capital city of Ethiopia, and 156 km away from Jimma, the capital city of Jimma Zone. Nonno Benja District was an area in the north by East Wallaga; in the south by the Chora Botor District found in the Jimma Zone; in the west by the Limmu Seka District found in the Jimma Zone; and in the east by the West Shoa Zone.

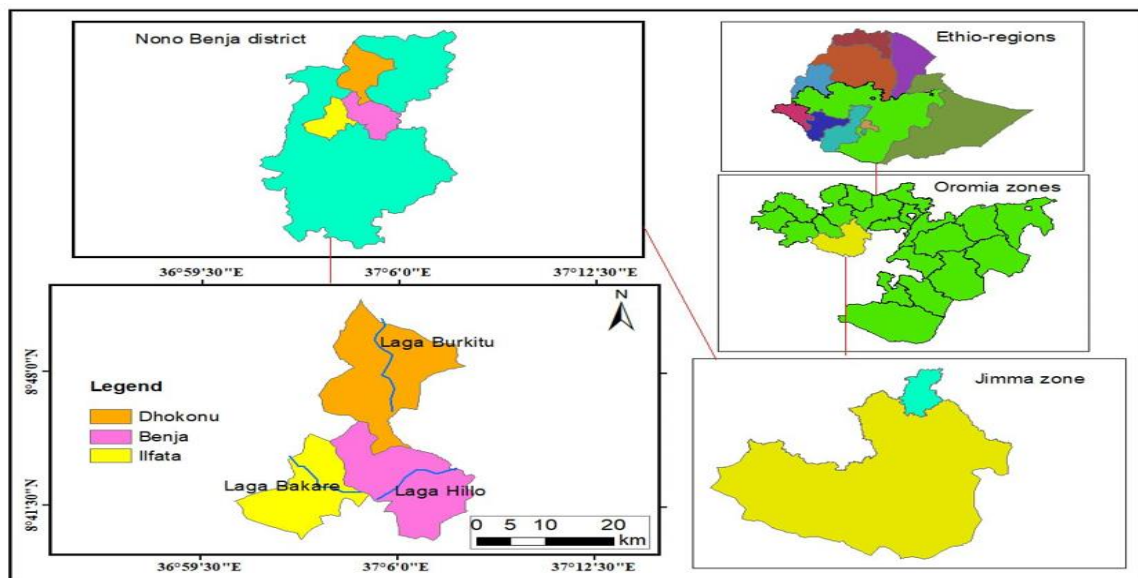


Figure 1. Map of Research area

The District has 19 rural and two urban kebeles. According to the population and housing census report (CSA, 2007), the total population of Nonno Benja District was 88204 (78103 rural dwellers and 10101 urban dwellers). The total population of the Noonoo Benja district has 36414 males and 51790 females. The 19 rural Kebele people were: Dokonu Kebele has 6238 people, Ilfeta Kebele has 5858 people, Benja Kebele has 5743, Beda Abayyi Kebele has 2565 people, Cawo Kebele has 4011 people, Konchi Kebele has 3700 people, Qoxo Kebele has 3803 people,

Sombo Dosha Kebele has 4122 people, Gurifat Kebele has 3849 people, and Sadi Werabo Kebele has 3144 people. Maxo Kebele has 3750 people, Weyyu Kebele has 4100 people, Amdo Kebele has 4036 people, Abiyyu Gibe Kebele has 3633 people, Abiyyu Sombo has 3945 people, Qolaxi Kebele has 3930 people, Borama Kebele has 3812 people, Soloqa Kebele has 3540 people, and Rogge Kebele has 4324 people. The physical features of the Nonno Benja District were generally hills, mountains, gorges, slopes, valleys, and plateaus; a few were flat and averagely gentle lands. The altitudes of the district ranged from 1600 m to 2600 m above sea level (Tefera, 2011). The annual average temperature of the Nonno Benja district ranges from 17.5°C to 22°C, whereas the annual mean rainfall ranges from 1300 to 1600 mm. The district has three climatic zones: middle land 58%, high land 18%, and low land 24% (Tefera, 2011).

3.2. Apparatus and Equipment

A prewashed polyethylene bottle was used to collect a drinking water sample. Measuring cylinder, pH meter, thermometer, conductivity meter, beakers, funnel, hot air oven, desiccator, filter paper, conical flask, measuring balance, polyaluminum, and volumetric flask were used for the working purpose. The preservation function of the sample was acidified with nitric acid and hydrochloric acid. After acidification, the water sample was kept in a refrigerator at 40°C to stop any change in volume due to evaporation, and Flame Atomic Absorption Spectroscopy (FAAS) was used to measure the concentration of heavy metals in the drinking water sample.

3.3. Chemicals and Reagent

The reagents used in the study were all the analytical grades, HNO_3 (70%) and HCl (37%), which were used for the digestion of the water sample. The concentration stock standard solution of 100 mg/L in 70% HNO_3 of the salts metals (Cd, Pb, and Zn) was obtained and used for the preparation of the calibration standards of each metal (Ravishankar, 2024). Working standards were produced between standards of each metal. Deionized water is also used for sample preparation, dilution, and rinsing apparatus before analysis.

Potassium nitrate (KNO_3), ammonium molybdate tetrahydrate 99.3%, hydrazine sulfate 99%, and potassium dihydrogen orthophosphate anhydrous 99.5% were used for the determination of phosphate ion and nitrate ion.

3.4. Collection of Water Sample

The water sample was collected from Laga Hillo, Laga Burkitu, and Laga Bakare found in the Nonno Benja district. The three streams of drinking water were collected from three kebeles based on the number of populations used. Every bottle was to be washed 3 times with the sample water before the collection of the sample. Water samples were collected during the morning at 2:00, day at 7:00, and evening at 12:00 pm. After collected, water sample was mixed in 1 L of polyethylene precleaned bottles. Cleaning helped to ensure that the collected samples were as representative of the water place as possible, with no interference from external materials. After that, the samples were labeled with the specific code and transported to Wallaga University's chemistry laboratory room and stored in a refrigerator at 40°C until the analysis. During transport, samples were kept in containers, particularly to protect against contamination or evaporation, and were analyzed within 24 hours.



Figure 2. Drinking Water sources under study captured at Nonno Benja District

3.5. Experimental Procedures

3.5.1 Cleaning Apparatus

Apparatus such as plastic containers and polyethylene bags were washed with lightly water using removing dirt, followed by cleaning with deionized water. The apparatuses were being wet in about 70% nitric acid, followed by cleaning with deionized water several times. Then, the apparatus was dried in the oven and kept in a dust-free place until further used.

3.6. Analytical procedures for some Physico-chemical parameter properties

3.6.1. Electrical Conductivity

Conductivity (EC) was the basic physical parameter of water. Refers to the ability of water to conduct an electrical current in water over a certain distance. Usually measured in Siemens (S) per distance. The ability of water to conduct electricity comes from the concentration of ions within water. The EC of collected samples was determined electrometrically by a conductometer (Micro-processor Based conductivity/TDS Meter model 1601). To use the conductivity meter, the conductivity meter electrode was calibrated with 0.1 M KCl. 100 mL of water samples were transferred into a beaker and the electrical conductivity was measured (Manimaran *et al.*, 2024).

3.6.2. The pH Meter

The pH of drinking water was one of the physico-chemical parameters. Calibrate the meter and rinse the electrode with distilled water to avoid contamination. Adjust the meter to read exactly. The pH of stream drinking waters was determined at Nonno Benja District. To use the portable pH meter, the pH electrodes was calibrated with the water sample several times (Rajab *et al.*, 2025).

3.6.3. Temperature

Temperature was measured the kinetic energy of molecules in the water. Temperature was one of the most essential physico chemical parameters of water quality (Khaliq *et al.*, 2024).

3.6.4. Total Dissolved Solid

Total dissolved solids (TDS) were to come from the water from sewage, agricultural runoff, industrial wastewater, or the use of water treatment chemicals. The more TDS that is dissolved or mixed in drinking water, the higher the conductivity. The total dissolved solid in water was measured by microprocessor-based conductivity (TDS Meter model 1601).

3.6.5. Total Suspended Solids (TSS)

Total Suspended Solids (TSS) was one of the methods to define analyses of suspended solids in drinking water. The measurement of solid particles, both organic and inorganic, that remains in suspension in water is called TSS.

Calculation for TSS was as follows (Gong *et al.*, 2025).

$$\text{TSS} = \frac{\text{final weight(mg)} - \text{initial weight(mg)}}{\text{volume of water(mL)}} \times 1,000,000 \text{ -----1}$$

3.6.6. Determination of nitrate ion and phosphate ion

3.6.6.1. Analysis of nitrate ion

The analytical producer for the determination of nitrate ion in spring drinking water was 2 mL of HCl and 0.1805 g of KNO_3 mixed in 500 mL of beaker with deionized water. After being dissolved in deionized water, it was transferred to a test tube and the concentration of nitrate in each spring drinking water was determined by UV-Visible (Kapp *et al.*, 2025).

3.6.6.2. Analysis of phosphate ion

The method to give in the identification of phosphate ions was dependent on the formation of a phosphomolybdate complex due to the reaction between molybdate and phosphate. The reaction was followed by its reduction with hydrazine hydrate in an aqueous acidic medium. Orthophosphate and molybdate ions condense in acidic solution to give molybdophosphoric (phosphomolybdic) acid, followed by selective reduction with hydrazine hydrate to form a blue color (Pratiwi *et al.*, 2024). The results of phosphate levels in stream drinking water samples from various sampling sites in the Nonno Benja district are shown in Tables 5 and 7 below.

3.6.7. Sample Digestion

The water samples were digested following standard procedures. Accordingly, 100 mL of a homogenous sample was transferred into the beaker; 3 mL of concentrated HNO_3 and 1 mL of concentrated HCl were added to the getter. Then the sample was covered by a ribbed watch glass and heated on a steam bath until the volume reduced to 25 mL. Then the cooled sample was transferred to a measuring cylinder and adjusted to 100 mL. Similarly, a blank sample was digested to do a blank correction. This was done by transferring 100 mL of distilled water into a beaker and digesting it as explained above. Finally, the concentrations of the listed heavy metals were determined by FAAS.

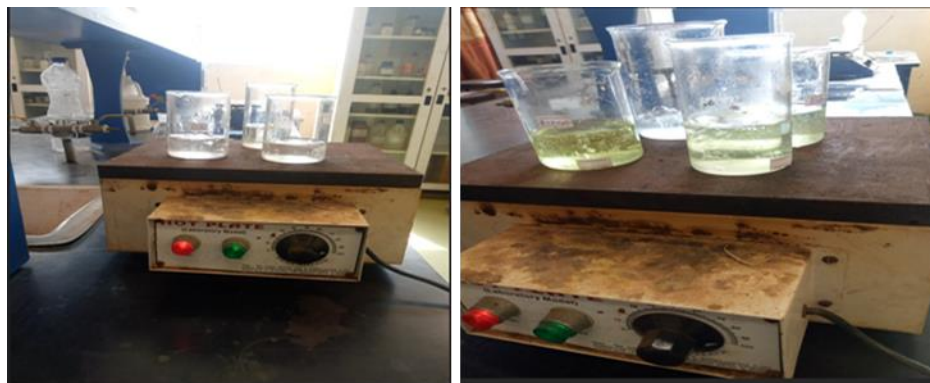


Figure 3. Hot plate Digester

3.6.8. Instrumental Operating condition

The instrumental operating conditions for FAAS employed for each analyte were given in **Table 8**. Secondary standard solutions containing 50 mL were prepared in a 100 mL volumetric flask for the atomic absorption spectrometer standard stock solution that contained 100 mg/L, which was prepared from soluble salts of each metal: $\text{Cd}(\text{NO}_3)_2$, $\text{Zn}(\text{NO}_3)_2$, and $\text{Pb}(\text{NO}_3)_2$ (Prajapati *et al.*, 2024). These secondary standards were diluted by deionized water to obtain three working standards for each metal of interest. Then Cd, Zn, and Pb were analyzed by FAAS (Model: 500) equipment presence of standard using an external calibration curve after the parameter (mean, S D, and linear range for maximum standard deviation of the instruments). Three replicated determinations of heavy metals were carried out for each sample. The metals were determined by

concentration versus absorbance mode, and then the instrument readout was recorded for each sample solution manually.

The data qualities obtained from FAAS for metal analysis were highly sincere by the calibration and standard sample solution preparation procedures. Then the instrument was calibrated using the event of standard working solutions of each metal that were prepared recently by acceptable dilution of the intermediate standard solution. The intermediate standard solutions were prepared from stock solutions of each metal. The concentrations of the intermediate working standard solutions and values of correlation coefficients of the calibration curve for nitrate ion, phosphate ion, and the three metals of interest existed, and their calibration curves were in the pictures of appendices 1, 2, 3, and 4 at the end of this paper.

3.6.9. Validation Method

The validation method was the process of providing that the analytical method was acceptable for its intended purpose. Precision, linear dynamic range, and interfering corrections were established for each individual target of analyte, and the certified reference material was used to observe accuracy. A valid and accurate FAAS method was developed to estimate the heavy metals in drinking water samples. Because of the absence of certified reference material for the samples in the laboratory, the validity of the digestion procedure was definitely by spiking the samples with the standard of known concentration of the analyte ground. The spiked samples were digested in triplicate, followed by the same digestion procedure developed previously for water samples (Yohannes *et al.*, 2024). Finally, the percentage of recovery was determined by using the formula for recovery (Chen *et al.*, 2024).

$$\% \text{ Recovery} = \frac{\text{amount of analytical covered}}{\text{amount of analytical added}} \times 100 \text{ -----}2$$

3.6.10. Analytical precision

The analytical precision of the procedure was usually expressed as the variance, mean, and relative standard deviation of each measurement. In this study, the precision of the results was evaluated by the percentage standard deviation of the results of the three replicate samples and

triplicate reading for each sample procedure with nine measurements for a given blank sample (Pigliasco *et al.*, 2024).

$$\% \text{ RSD} = \frac{SD}{\bar{x}} \times 100 \text{ ----- } 3$$

3.6.11. Statistical Analysis

The data was determined by using SPSS software. The data collected for the laboratory were a set of determinations that was subjected to statistical analysis (SAS), which was done by SPSS software. All analyses were carried out in triplicate, and the data was presented in both mean $\pm$ standard deviation (mean $\pm$ SD) and variance of the sample.

UNIT FOUR

RESULTS AND DISCUSSION

4.1. Physico-Chemical Analysis

4.1.1. Analysis of sample water

The proximate water samples were essential to obtain a handful of information about the nature of the samples. Choosing physicochemical parameters for testing the water sample only depended on what purposes we were going to use it for and how important we needed its quality and purity. The drinking water samples were subjected to the measurement of some physicochemical parameters like pH, temperature, total dissolved solids, total suspended solids, electrical conductivity, nitrate ions, and phosphate ions to prove in the following **Table 2 and 5**.

Table 2. Various physic-chemical parameter of spring water Mean $\pm$ SD values and variance

Parameter	Unit	Sample sites		
		Laga Burkitu	Laga Bakare	Laga Hillo
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
Temperature	$^{\circ}$ C	20.933 $\pm$ 0.11547	20.9667 $\pm$ 0.05774	21.7667 $\pm$ 0.25166
PH	—	6.4167 $\pm$ 0.01528	6.4033 $\pm$ 0.01528	6.8633 $\pm$ 0.01528
TDS	mg/L	54.333 $\pm$ 0.15275	34.4667 $\pm$ 0.05774	68.9000 $\pm$ 0.17321
TSS	mg/L	0.2103 $\pm$ 0.00950	0.3170 $\pm$ 0.00531	0.4051 $\pm$ 0.00465
EC	μ s/cm	84.1667 $\pm$ 0.05774	52.9667 $\pm$ 0.05774	105.5000 $\pm$ 0.34641

Temperature: The Thermometer was calibrated earlier sample determination using by Thermometer and standard buffer solution of 50 mL sample was taken into a clean beaker and the electrode go under the surface solution and Reading was undergone when the meter become completed. From **Table 2** the ranges of temperature were from 20.93 $^{\circ}$ C - 21.77 $^{\circ}$ C in Burkitu, Bakare and Hillo. The values reported in this work was lower level of the range accepted by WHO (25 $^{\circ}$ C) and Ethiopian standard guideline values for drinking water. Then, the observed temperature of the studied sites were not significant and the water sources were acceptable for drinking and other purpose concerning with temperature.

pH: It was the measure of the hydrogen potential of water and used to express the quality of the acidity or alkalinity of water sample. The pH was determined by electrometric method using pH

meter (Lewenstam *et al.*, 2025). The minimum mean value was 6.4033 (Bakare) and the maximum mean value was 6.8633 (Hillo). Briefly, laga Hillo (6.85-6.88), laga Burkitu (6.40-6.43) and laga Bakare (6.39-6.42) have pH values. The average pH of laga Hillo 6.863, Laga Burkitu 6.42 and Laga Bakare water sample was 6.403 measured. The pH of the stream water sample increasing order Laga Hillo 6.863 greater than Laga Burkitu (6.42), Laga Burkitu (6.42) greater than Laga Bakare (6.403) and this result was below of WHO (6.5-8.5) permissible limits and Ethiopian standard guide line of drinking water. For this reason those stream water not harmful for drinking and other purpose.

Total Dissolved solid (TDS): The total dissolved solid in steam drinking water was measured by a microprocessor-based conductivity model 1601, and the standard buffer solution in 50 mL of sample was taken into a clean beaker, and the electrodes were submerged. Reading of the electrode when it underwent stabilization recorded a number on the mark. The measured TDS values were found between the minimum value of 34.47 mg/L (Bakare) and the maximum value of 68.90 mg/L (Hillo) (**Table 3**). The results were below the standard set by the WHO (500 mg/L) and Ethiopian standard guidelines for drinking water permissible limits. This indicates that no problem is concerned with the TDS of the studied stream water sample. Hence, those ranges were acceptable, and the value of TDS was not dangerous for drinking and other benefits.

Table 3. Mass of total dissolved solid in water sample

Sample sites	Mass of total dissolved solid in ppm	Av in ppm
Laga Burkitu	54.3, 54.5, 54.2	54.33
Laga Bakare	34.5, 34.4, 34.5	34.47
Laga Hillo	68.8, 68.8, 69.1	68.9

Total Suspended Solid (TSS): Total suspended solids determine the level of organic matter that is present in the drinking water sample. Accordingly, a total suspended solid in sample sites was written in **Table 4** below.

Table 4. Mass of total suspended solid in water sample.

Sample sites	Mass of suspended solid in mg/L	Av in mg/L
Laga Burkitu	0.2199,0.2102,0.2009	0.2103
Laga Bakare	0.3191,0.3210,0.3110	0.3170
Laga Hillo	0.4105,0.4025,0.4024	0.405

The range of total suspended solids in the Laga Hillo drinking water sample was (0.4024-0.4105) mg, Laga Bakare (0.311-0.321) mg, and Laga Burkitu (0.2009-0.2199) mg/L. The minimum average value was 0.2103 (Burkitu) and the maximum average value was 0.4051 (Hillo) (**Table 4**). According to WHO and Ethiopian standard guidelines, less than 30 mg/L. Laga Hillo was river water because of more contamination with suspended solids. This result did not exceed the WHO and Ethiopian standard guidelines and is not harmful for drinking and other purposes.

Electrical conductivity (EC): EC was measured for the conducting ability of drinking water and greatly determined the ionic species that were present in the water sample. Those ions were anions and cations present in drinking water and also depended on the mobility of the ions at a given temperature. It measured the conductivity and ion mobility in the drinking water sample, and it shows the presence of dissolved ions, and greatly electrical conductivity was caused by higher ionizable salts in the water sample. To make 9 conductivity measurements, the electrode was immersed in 100 mL samples until a steady reading was reached. The range of conductivity of drinking water samples was (52.97-105.5) $\mu\text{S/cm}$, Laga Hillo, Laga Burkitu, and Laga Bakare (**Table 2**). The minimum value EC was recorded at the Bakare site (52.97) $\mu\text{S/cm}$ stream water, and the maximum value was recorded at the Hillo site (105.5) $\mu\text{S/cm}$ stream water. According to WHO standards, the EC value should not exceed 400 $\mu\text{S/cm}$ (WHO, 2024). The data obtained in all sampling sites were within the standard data; no problem was concerned with EC if the water was used for drinking and other benefits.

4.2. Calibration of the instrument of nitrate and phosphate

The calibration of the instrument was done by the preparation of a standard solution before the analysis of nitrate ion and phosphate ion in drinking water. Because of the qualities of the result obtained from nitrate ions and phosphate ions analysis using a UV-visible spectrophotometer, it was seriously affected by the calibration and preparation of the standard solution correctly. The standards were prepared from 100 mg/L of nitrate and phosphate by taking in 3 mL of HNO₃ of the concentrations in each water sample written in **Table 5**. The calibration curves of the nitrate on the 220 nm wavelength and phosphate to be determined in 641 nm.

Table 5. Concentration of nitrate and phosphate ions of the water samples with different wave length (nm) (Mean ± SD values and variance) (mg/L)

Sample	NO ₃ ⁻ (220 nm)		Po ₄ ³⁻ (641 nm)	
	Mean±SD	Variance	Mean±SD	Variance
Laga Burkitu	4.4794±0.00393	0.00	0.1772±0.4083	0.002
Laga Bakare	1.2861±0.00104	0.00	0.0583±0.01582	0.00
Laga Hillo	0.4227±0.21390	0.046	1.3681±0.23550	0.055

Nitrate (NO₃⁻): The presence of in the analyzed water sample could be believed with agricultural activities. Excreta from humans and animals may contribute to levels in the waterways under study. The presence of this in these waterways was likely due to its natural availability in the water. Was soluble in water and entered drinking groundwater. A higher rate of nitrate in water was a causative factor in cancers (Sanjupriya *et al.*, 2025). The concentration of ions in the studied sites varied between a minimum value of 0.423 mg/L at (Hillo) and a maximum value of 4.48 mg/L at (Burkitu). There was no agricultural area around the sample site; the concentrations of ions in Hillo and Burkitu might be due to the presence of nitrogen occurring naturally in the soil and organic forms from decayed plant and animal residues that were changed to by bacteria and leached to study spring water. The obtained results were below the currently recommended guideline values for drinking water standards (50 mg/L), which were given by WHO (2024) and Ethiopian guideline values for drinking water quality, indicating that no health problem was associated with the level of the examined stream water.

Table 6. Concentration of standard nitrate (220 nm) in Water Sample

Standard	Concentration of standard (mg/L)	Absorbance(220nm)	Correlation coefficient (R^2) calibration curves
1	1.000	0.7386	0.991888
2	2.000	0.9775	0.991888
3	4.000	1.3823	0.991888
4	7.000	1.7828	0.991888

Phosphate (PO_4^{3-}): was another important chemical parameter for water quality and influences the taste and odor of drinking water (Palaka *et al.*, 2025). Phosphates were forms of phosphorus, a critical nutrient in ground and freshwater ecosystems. A small amount of phosphate was essential for aquatic life; excessive amounts can lead to environmental problems such as eutrophication. Mostly, orthophosphate was the bioavailable form for algae and aquatic plants (Tasnim, 2025). The current study was the minimum ion concentration recorded at Laga Bakare (0.0583 mg/L) and the maximum recorded at Burkitu (1.37 mg/L) stream water. In the present study, all of the samples had greater than the recommended level above the WHO standard guideline, which was 0.03 mg/L. There was a different concentration of ions among the stream water sample sites. Therefore, the content of the studied sites of water samples was not a suitable standard for drinking and other domestic purposes according to WHO standard guidelines.

Table 7. Concentration standard of sample phosphate (641nm) in water sample

Standard	Concentration (mg/L)	Absorbance(641nm)	R^2
1	0.500	0.0002	0.990418
2	1.000	0.0016	0.990418
3	1.500	0.0045	0.990418
4	2.000	0.0058	0.990418
5	2.500	0.0090	0.990418

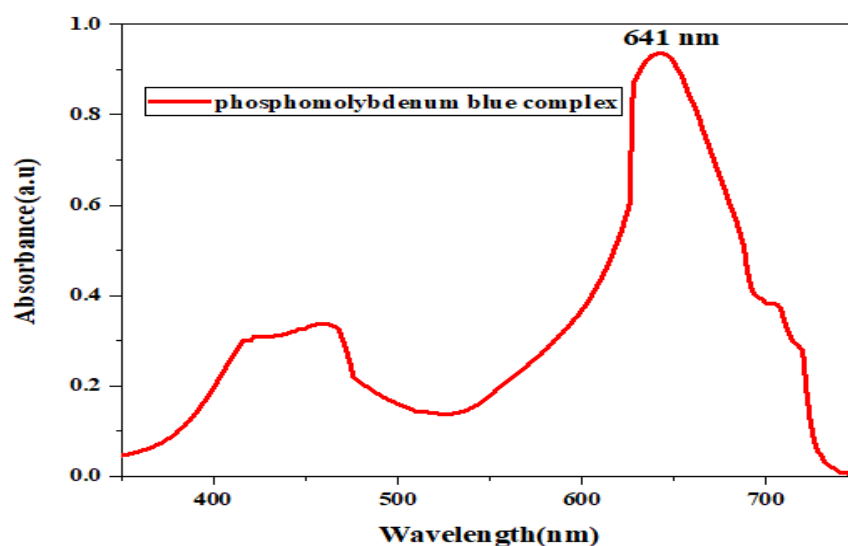


Figure 4 UV-Visible spectrum of phosphomolybdenum blue complex

4.3 Heavy metals analysis of the different stream water samples

The presence of heavy metals in drinking water higher than a certain concentration can cause detrimental impacts on human health (Jomova *et al.*, 2025). Heavy metals were not biodegradable and tended to accumulate in the sediments of waterways in association with organic and inorganic matter (Mansor *et al.*, 2024). Thus, the measurement of heavy metals in drinking water was the crucial metric, and a majority of drinking water quality research included heavy metal analysis. The results of the current study were compared with the WHO-established acceptable limits and Ethiopian standard for drinking water quality guidelines of heavy metals such as Cd, Zn, and Pb. Drinking water standard metals that were found in water in excess of certain maximum permissible amounts, such as Cd, Zn, and Pb, were deemed hazardous for human consumption. The maximum allowable concentrations for the heavy metals Cd, Zn, and Pb were recommended by WHO, and Ethiopian guideline values for drinking water quality were 0.003 mg/L, 5.0 mg/L, and 0.01 mg/L, respectively.

Table 8. Mean ± Standard Deviation of heavy metal Concentration (mg/L).

Parameter	Laga Burkitu		Laga Bakare		Laga Hillo	
	mean±SD	Variance	mean±SD	variance	mean±SD	variance
Pb	2.43± 1.21	7.009	3.02± 0.045	4.833	1.34± 0.66	21.741
Zn	3.61± 0.028	0.001	3.18± 0.038	0.001	1.73± 0.024	0.001
Cd	2.86± 0.03002	0.001	0.0254± 0.0113	0.001	0.098± 0.0301	0.001

Lead (Pb): The levels of Pb are 2.43 ± 1.21 mg/L for Laga Burkitu, 3.02 ± 0.045 mg/L for Laga Bakare, and 1.34 ± 0.66 mg/L for Laga Hillo. Pb is a metal not useful in the human body and does not dissolve easily into the environment. Therefore, it can be mixed with soil particles and enter underground water or drinking water following rain and surface water runoff. Pb was a toxic heavy metal and can affect many organs in the human body (Jomova *et al.*, 2025). Pb is more in the skeleton, and its mobilization from bones during pregnancy and lactation causes exposure to fetuses and breastfed infants. The permissible value of Pb concentration in drinking water was 0.01 mg/L (WHO, 2024) and 0.007 mg/L (Ethiopian standard guideline) for drinking water. In the current study, the researcher identified the level of Pb in all samples of stream water that were detected. The concentration of Pb ranges from 1.34 to 3.02 mg/L, which is greater than the value of 0.01 mg/L recommended by WHO (2024) and the 0.007 mg/L Ethiopian standard guideline. The level of Pb in three sites was above the standard values set by WHO and Ethiopian guidelines for drinking water quality, and the study indicated a potential health hazard to consumers and other activities.

The level of Pb in the stream drinking water was significant (laga Bakare > laga Burkitu > laga Hillo) in the water sample in **Table 8**. The Pb was higher than the permissible limit for drinking water standards set by WHO (0.01) and Ethiopian standards (0.007). The stream drinking water was not suitable for human and other domestic purposes because Pb was a toxic heavy metal even at low levels, and chronic harm had been linked to growth retardation for children.

Zinc (Zn): The mean value for Zn concentration ranges from 1.73 mg/L (Hillo) to 3.61 mg/L (Burkitu). The lower concentration was at Laga Hillo and the higher concentration at Burkitu. In Laga Hillo and Laga Burkitu, the Zn concentration of stream water is less than the WHO 3.0 mg/L, and only Laga Bakare is greater than the WHO permissible limit, and all are below the 5.0 mg/L Ethiopian standard guideline for drinking water (**Table 1**). Therefore, based on the findings of this investigation, there are no negative consequences associated with the Zn concentration in the drinking water samples from Laga Hillo and Burkitu. The drinking water from the Laga Bakare stream had a zinc concentration that was higher than the WHO (3.0 mg/L) and lower than the Ethiopian standard (5.0 mg/L), which is harmful for drinking and other household items for Laga Bakare because of the high concentration of zinc in the case of volcanic rock and agricultural activities.

According to the study, the Zn concentrations in the three water streams varied between 1.73 and 3.61 mg/L, indicating a substantial difference between the Laga Burkitu and Laga Bakare and Laga Hillo water samples (**Table 8**). Zinc contents in two of the sample sites, Laga Burkitu and Laga Hillo, were less than the WHO and Ethiopian standard allowable level. In the presence of naturally occurring minerals and agricultural activities in the research area, the zinc metal may be the cause of the increased concentration of zinc in the stream water (Bakare). The zinc content (1.705 mg/L) exceeded the WHO's reported threshold of 3.0 mg/L (2024). The concentration of Zn in the one sample of water was greater than the WHO (2024) guideline value (3.0 mg/L) and less than the 5.0 mg/L Ethiopian standard guideline for drinking water. This showed that the two streams of water studied had more pollution of Zn and were therefore acceptable for drinking purposes and other domestic activities according to WHO.

Cadmium (Cd): The permissible value of Cd concentration in drinking water was 0.003 mg/L (WHO, 2024) and 0.006 mg/L (Ethiopian standard guideline). The researcher identified the level of Cd in all samples of stream water that was detected. The concentration of Cd in the three study sites was above recommended WHO and Ethiopian guideline values for drinking water quality, and the study indicated a potential health hazard to consumers and other activities.

Cd concentrations in all three different streams of water samples were above the detection limit of the instrument FAAS (Model: 500). The concentration range of Cd (0.0254-2.86 mg/L) was greater than the value of 0.003 mg/L reported by WHO and the 0.006 mg/L Ethiopian standard.

The average Cd concentration in three sample sites was 0.99 mg/L. This indicates that the concentration of cadmium in all the study sites, Laga Hillo, Laga Bakare, and Laga Burkitu, was above the WHO (2024) guideline and Ethiopian standard guideline in drinking water. The decreasing order of Cd concentration is laga burkitu > laga hillo > laga bakare, respectively.

Table 9. Working standard concentration and correlation coefficients of heavy metal concentration by using FAAS

Metals	Concentration in (mg/L)	R ²	Equation for calibration curve
Cd	1,2,3,4,5	0.9984	$y = 0.1191x - 0.0003$
Pb	1,2,3,4	0.9972	$y = 0.0119x + 0.0025$
Zn	1,2,3,4,5	0.9986	$y = 0.0032x + 4E-05$

4.3.1. Distribution patterns heavy metal in different spring sample water

The analysis's outcome demonstrated that the level of the heavy metal identified in the three sample stream waters varied. In general, from that, the average concentration of Pb in all sample sites was 2.263 mg/L. The higher concentration of all the heavy metals followed the Zn (2.84 mg/L), while Cd (1.13 mg/L) was the least among the concentrations of the heavy metals obtained because the concentration for cadmium was the minimum detection of the instrument when compared with Pb and Zn. Pb, and Cd concentrations were found to be above the WHO and Ethiopian standard guideline maximum concentrations. On the whole, samples analyzed from all streams showed the presence of Pb, Zn, and Cd. In short, the concentrations of heavy metals in the stream drinking water samples were listed in decreasing order as follows: Pb > Zn > Cd (since the concentrations of Pb and Cd were above the permissible limit of the instrument). Generally, the result of the analyzed heavy metal showed that the stream with the highest concentration of Pb was Laga Bakare, followed by Laga Burkitu stream water, and the stream that has the lowest

concentration of Zn and Cd was Laga Hillo stream water. Therefore, a person who consumes Laga bakare and Laga burkitu stream drinking water was exposed to the toxic effects of lead and Cd more than those people who drink Laga Hillo drinking water.

Table 10. Ranges of metals concentration in three stream water samples

Metals	Range of Metal Concentration in mg/L			Over all Range (mg/L)
	Laga Hillo	Laga Bakare	Laga Burkitu	
Pb	0.645 -2.43	1.33-3.02	0.45-1.33	0.45 – 3.02
Zn	1.705 -1.752	2.86-3.18	3.02-3.61	1.705 – 3.61
Cd	0.23 -3.26	0.023-0.0254	0.063-0.0974	0.023 – 3.26

The higher range levels of lead (0.45–3.02 mg/L), zinc (1.705–3.61 mg/L), and cadmium (0.023–3.26 mg/L) in the stream water may be due to the fact that organic mineral decomposition for a long period of time or from lead, zinc, and cadmium metals that were organic compounds occurred around the Earth's crust and in the presence of agricultural activities around stream drinking water.

4.4. Pearson correlation of physicochemical parameter and heavy metals

The Pearson's correlation coefficient was used to determine the link between various heavy metal concentrations and some of the physicochemical parameters. The higher the correlation coefficient (near +1 or -1), the higher the quality between two variables, and the concentration was nearly zero, meaning there was no relationship between them at a significant level of 0.05%, which can be strongly correlated. Pearson correlation of physico parameters and heavy metals of stream drinking water was performed to assess possible similar sources of physico parameters and heavy toxic metals. The physico-parameter and heavy metals with positive correlation were considered to have similar sources.

The correlation analysis showed a strong correlation between phosphate and nitrate, zinc and phosphate, cadmium and zinc, and a moderate correlation between electrical conductivity with total dissolved solids and phosphate with pH. The pH has a strong correlation with temperature owing

to the generation of either hydrogen ion or hydroxyl ion into water so that it alters the values accordingly. The EC showed a strong correlation with Cd, indicating the availability of soluble salts of Cd (NO_3^-)₂ in the rocks or other sources. Similarly, a strong correlation was observed between Zn and, as well as between Cd and NO_3^- .

Table 11. Correlation coefficient of some physico-parameter and heavy metal in water sample

	Temp	pH	TDS	TSS	EC	NO_3^-	PO_4^{3-}	Pb	Zn	Cd
Temp	1									
pH	-.99*	1								
TDS	.80	-.75	1							
TSS	-.91	.98	-.86	1						
EC	.91	0.945	.50	-.87	1					
NO_3^-	-.91	.94	-.50	.87	-.1.00**	1				
PO_4^{3-}	-.74	.69	-.42	-.99	-.59	.99	1			
Pb	.29	-.22	.80	-.39	-.10	.10	-.85	1		
Zn	-.72	.66	-.99	.78	-.38	.38	.99*	.23	1	
Cd	-.89	.92	-.46	.84	-.99*	.99*	.38	-.82	.93	1

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

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

4.5 Assessment of Human Health Risk

Risk assessment was defined as the methods of evaluating the probability of occurrence of any given probable amount of the harmful health impacts over a determined time period (Farahmandkia *et al.*, 2025). The health risk assessment of each contaminant is normally based on the estimation of the risk level and is classified as carcinogenic or non-carcinogenic health hazards (Eslamizad *et al.*, 2025). To determine heavy metal impurity and potential carcinogenic and non-cancer health risks via ingestion and dermal absorption of heavy metals in the water of the shared Nonno Benja District, Hazard Quotients (HQ), Hazard Index (HI), and the Incremental Lifetime Cancer Risk (ILCR) were used. The studied group was adults.

$$CDI_{\text{ingestion}} = \frac{C \cdot W \cdot DI \cdot ABS \cdot EF \cdot EP}{WB \cdot AT} \text{-----}4$$

$$CDI_{\text{dermal}} = \frac{C \cdot W \cdot SA \cdot KP \cdot ABS \cdot ET \cdot EF \cdot EP \cdot CF}{WB \cdot AT} \text{-----}5$$

Where Cw in mg/L was the level of heavy metals in water, SA in cm² was the skin area found for contact, Kp in cm/hour was the permeability coefficient, ABS unitless was the dermal absorption factor, DI in L/day was the daily average intake of water in the area, ET (in h/event) is the exposure time, EF (in days/year) represented the annual exposure frequency, EP (in years) was the exposure period, CF (in L/cm³) was the unit conversion factor, BW (in Kg/person) was the body weight, and AT (in days) was the average time.

1. Hazard Quotient (HQ): The HQ for each heavy metal was estimated using the ratio of computed mean daily intake (ADI, mg/kg/day) of a metal ingested with contaminated water to the reference oral dose (R_fD) through oral ingestion and dermal absorption for the residents. The sum of all HQs gave an estimation of total potential health risks or HI (Yazman *et al.*, 2024).

The calculation of the HQ caused by water was presented as (Equation 6):

$$HQ = \frac{CM \times IR \times EF \times ED}{AW \times AT} \text{-----}6$$

Where CM = heavy metal levels in water mg/Kg weight, IR = ingestion rate of water considered to be 65 g/person/day, EF = exposure frequency (365 days/year), ED = exposure duration (70 years), AW = adult body weight 70 Kg, and AT = average exposure time for non-carcinogenic health risk determined as ED × 365 = 25,550 days.

2. Health Hazard Index (HI): is used to calculate the total potential non-carcinogenic health effect caused by exposure to a combination of heavy metals in water. The HI for several heavy metals was computed according to the EPA guidelines for health risk assessment (Enkhjargal *et al.*, 2025). Using the following Equation 7.

$$HI = \sum_{k=1}^n HQ = HQ_{Pb} + HQ_{Cd} + HQ_{Zn} \text{-----}7$$

Pb = 0.0021, Zn = 0.00264, Cd = 0.00105 HI were calculated. So the HI value of heavy metal in the spring drinking water was HI < 1 and not harmful for drinking and other purposes. HI > 1

addition that there were potential health risks, while $HI < 1$ was regarded as safe. The minimum, mean, and maximum levels of heavy metals (Pb, Cd, and Zn) present in water samples in the distribution network of the Nonno Benja district were presented in **Table 12**.

Table 12. Health Hazard Index of sample sites

Parameter	HI Burkitu	HI Bakare	HI Hillo	Total HI
Pb	0.00227	0.0028043	0.001241	0.00211
Zn	0.0034	0.002953	0.001604	0.002652
Cd	0.00302	0.000024	0.0009044	0.00132

For all samples, the HI is less than 1, implying that the water is safe for drinking even though the levels of three heavy metals were above the permissible limits of WHO and other organizations.

Table 13. Some physico parameter and Heavy metal concentrations in the water distribution network of the study area (Zhang et al., 2024).

Physic parameter and Heavy metal concentrations (mg/L)				Standard Drinking water (mg/L)	
Parameter	Mean	Minimum	Maximum	Ethiopia (2024)	WHO (2024)
Temp	20.933	20.80	22.00	-	-
pH	6.417	6.39	6.88	6.5-8.5	6.5-8.5
TDS	54.333	34.40	69.10	1000	1000
TSS	0.210	0.20	0.41	-	-
EC	84.167	52.90	105.70	1500	400
NO_3^-	4.479	0.27	4.48	50	50
PO_4^{3-}	0.177	0.04	1.64	0.03	0.01
Pb	2.263	1.34	3.02	0.007	0.01
Zn	2.84	1.73	3.61	5.0	3.0
Cd	0.9945	0.0254	2.86	0.006	0.003

The pH and values of the three water samples were slightly lower or greater than permissible limits of Ethiopia and WHO, while the TDS and EC were far lower than the standard values. The levels of heavy metals like Pb, Cd, and Zn are greater than the recommended limits set by WHO

and Ethiopia, showing that there is a concern related to the health implications of the consumers. However, the HI values of the three drinking water samples show the water is safe for adults consuming it.

UNIT FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The purpose of this research was to determine the level of some physicochemical parameters and the concentration of heavy metals in water samples from Burkitu, Bakare, and Hillo stream water sources. In this study, physicochemical parameters such as pH, temperature, EC, TDS, TSS, and heavy metals (Zn, Cd, and Pb) of the stream waters were measured. The results showed that the concentration of some physicochemical parameters of the water sample, such as pH, temperature, EC, TDS, TSS, PO_4^{3-} , and NO_3^- ions, was below the permissible limit of the WHO (2024) and Ethiopian guideline (2024) values for drinking water quality standards. The average values of temperature, pH, EC, TDS, TSS, range from 20.93-21.77 °C, 6.4-6.86, 52.97-105.5 $\mu\text{S}/\text{cm}$, 34.47-68.9 ppm, 0.21-0.41 mg/L, 0.046-4.4 mg/L, and 0.058 1.37 mg/L, respectively. Concentrations of Cd, Pb, and Zn in the samples of water obtained from the three streams were found to exceed WHO (2024) recommended limits. Average concentrations of the heavy metals in stream drinking water range from Pb (17.94-23.83 mg/L), which means Laga Bakare > Laga Burkitu > Laga Hillo; Zn (1.705-8.63 mg/L), which means Laga Burkitu > Laga Bakare > Laga Hillo; and Cd (1.012-10.439 mg/L), which means Laga Burkitu > Laga Hillo > Laga Bakare, respectively. Cd and Pb in all samples (1.0480 ± 0.03132 to $10.4097 \pm 10.4097 \pm 0.03002$ mg/L, 17.9413 ± 4.66275 to $23.8333 \pm 23.8333 \pm 2.19850$ mg/L) are greater than the values recommended by WHO (0.003 mg/L, 0.01 mg/L) and the Ethiopian standard guideline (0.006 mg/L, 0.007 mg/L), while Zn in Laga Burkitu (8.6107 ± 0.02765 mg/L) and Laga Bakare (8.1823 ± 0.03821 mg/L) is greater than the threshold values of WHO (3.0 mg/L) and USEPA (5.0 mg/L). The higher concentration of Pb in the Laga Bakare spring water may be due to the fact that emissions from land application of fertilizers, natural mineral decomposition for a long period of time, or Pb metals were occurring naturally in the Earth's crust. The overall concentration range of all heavy metals obtained from the three streams was above the WHO recommended limit and Ethiopian standard guideline; therefore, it may pose some health effects. However, the HI study shows the water from the three streams was safe for drinking according to the current findings.

5.2. Recommendation

From this research, it is recommended that:

- Since water was essential to life, the government and other relevant authorities must implement appropriate drinking water treatment methods that can lower the present levels of harmful heavy metals. Since just three heavy metals were examined in the study, more research should be done to examine other heavy metals, such as cobalt, mercury, arsenic, titanium, and others, as there may be some discrepancies.
- The amount of heavy metals present in various water sources that the residents of Nonno Benja District Jimma Zone, Oromia, Ethiopia, use for drinking should be investigated further.
- Almost all research on the physicochemical high-standard parameters of drinking water is very important to protect the health of the consumers.
- It was also necessary to raise community members' awareness and strengthen their capacity in order to safeguard spring water supplies from potential sources of pollution.
- It was also crucial to regularly assess the contaminants in the stream in order to preserve the consumer' health.
- It was identified pollution sources of contamination within the watershed, including agricultural runoff, industrial discharges, and urban wastewater.
- Encourage further studies to better understand the long-term trends in water quality and the ecological impacts of contaminants in the stream.

6. REFERENCES

- Abbas, Q., Yousaf, B., Ali, M. U., Munir, M. A. M., El-Naggar, A., Rinklebe, J., & Naushad, M. (2020). Transformation pathways and fate of engineered nanoparticles (ENPs) in distinct interactive environmental compartments: A review. *Environment international*, 138, 105646.
- Adekanmi, A. T. (2021). Health hazards of toxic and essential heavy metals from the poultry waste on human and aquatic organisms. *Animal Feed Science and Nutrition-Production, Health and Environment*.
- Adler, C. M. (2025). Fool me once, shame on you. Fool me twice, shame on us: Shattering the Illusion of Climate Security as a Means of Protecting Communities Facing Climate Disaster. *Turkish Journal of International Development*, 1(1), 149-172.
- Afata, T. N., Mekonen, S., & Tucho, G. T. (2023). Serum concentration of zinc, copper, iron and its associated factors among pregnant women of small-scale farming in western Ethiopia. *Scientific reports*, 13(1), 4197.
- Ahmed, S., Peterson, S. J., Parikh, M. A., & Frishman, W. H. (2025). Cardiovascular manifestations of hemochromatosis: a review of pathophysiology, mechanisms, and treatment options. *Cardiology in Review*, 33(4), 359-364.
- Ali, M. M., Hossain, D., Al-Imran, A., Khan, M. S., Begum, M., & Osman, M. H. (2021). Environmental pollution with heavy metals: A public health concern. *Heavy metals-their environmental impacts and mitigation*, 771-783.
- Al-Khuzai, M. M., Abdul Maulud, K. N., Wan Mohtar, W. H. M., & Mundher Yaseen, Z. (2024). Assessment of untreated wastewater pollution and heavy metal contamination in the Euphrates river. *Environmental Pollutants and Bioavailability*, 36(1), 2292110.
- Almaliki, A. J. D., Bashir, M. J., & Borrajo, J. F. L. (2022). Appraisal of groundwater contamination from surface spills of fluids associated with hydraulic fracturing operations. *Science of the Total Environment*, 815, 152949.
- Banda, T. D., & Kumarasamy, M. V. (2020). Development of Water Quality Indices (WQIs): A Review. *Polish Journal of Environmental Studies*, 29(3).

- Bao, T., Wang, P., Hu, B., Jin, Q., Zheng, T., & Li, D. (2024). Adsorption and distribution of heavy metals in aquatic environments: The role of colloids and effects of environmental factors. *Journal of Hazardous Materials*, 474, 134725.
- Biswas, A., Biswas, T., Guha, S., Maji, A., Das, G., Naskar, R., ...& Mondal, T. K. (2025). Adaptable coumarin-based fluorescent molecular multianalyte sensor for Zn ²⁺, Hg ²⁺ and Cu ²⁺ via different sensing modalities and its bioimaging applications. *Analytical Methods*, 17(33), 6707-6718.
- Budi, H. S., Catalan Opulencia, M. J., Afra, A., Abdelbasset, W. K., Abdullaev, D., Majdi, A., ... & Mohammadi, M. J. (2024). Source, toxicity and carcinogenic health risk assessment of heavy metals. *Reviews on Environmental Health*, 39(1), 77-90.
- Chen, X., Zhang, Q., Li, Y., Liu, J., Liu, Z., & Liu, S. (2024). Investigation on enhanced oil recovery and CO₂ storage efficiency of temperature-resistant CO₂ foam flooding. *Fuel*, 364, 130870.
- Daehn, I. S., & Duffield, J. S. (2021). The glomerular filtration barrier: a structural target for novel kidney therapies. *Nature Reviews Drug Discovery*, 20(10), 770-788.
- deCarvalho Machado, C., & Dinis-Oliveira, R. J. (2023). Clinical and forensic signs resulting from exposure to heavy metals and other chemical elements of the periodic table. *Journal of clinical medicine*, 12(7), 2591.
- Enkhjargal, O., Lamchin, M., You, X. Y., Chambers, J., Tuyagerel, D., Tovvudorj, R. ...& Enkhtuya, N. (2025). Carcinogenic and non-carcinogenic risk assessment of heavy metals in PM_{2.5} air pollutant in Ulaanbaatar, Mongolia during the wintertime. *Air Quality, Atmosphere & Health*, 18(2), 615-629.
- Eslamizad, S., & Alehashem, M. (2025). Metal contaminants in rice imported to Iran: A comprehensive assessment of carcinogenic and non-carcinogenic health risks. *Journal of Trace Elements in Medicine and Biology*, 87, 127568.
- Etale, A., Onyianta, A. J., Turner, S. R., & Eichhorn, S. J. (2023). Cellulose: a review of water interactions, applications in composites, and water treatment. *Chemical reviews*, 123(5), 2016-2048.

- Farahmandkia, Z., Tajdar-oranj, B., Zare, L., Peyda, M., Feizolahi, R., & Alizadeh, A. M. (2025). Health risk assessment of lead and cadmium in milk-based products of Iran. *Journal of Agriculture and Food Research*, 19, 101558.
- Feng, D., Wang, R., Sun, X., Liu, P., Tang, J., Zhang, C., & Liu, H. (2023). Heavy metal stress in plants: Ways to alleviate with exogenous substances. *Science of the Total Environment*, 165397.
- Fernandez-Figueroa, E. G., Rogers, S. R., Waters, M. N., & Wilson, A. E. (2024). The green convergence: United States lakes are collectively moving toward a eutrophic state. *Harmful Algae*, 139, 102721.
- Fisher, R. M., & Gupta, V. (2024). Heavy metals. In *StatPearls [Internet]*. StatPearls Publishing.
- Fouad, K., Popovich, P. G., Kopp, M. A., & Schwab, J. M. (2021). The neuroanatomical–functional paradox in spinal cord injury. *Nature Reviews Neurology*, 17(1), 53-62.
- Gerhardsson, L. (2022). Diagnosis and treatment of metal poisoning general aspects. In *Handbook on the Toxicology of Metals* (pp. 663-684). Academic Press.
- Gong, C., Zhang, H., Huo, S., Zhang, J., Weng, N., & Li, W. (2025). Transformation processes of total suspended solids and dissolved organic matter in rivers: Influences of different land use sources and degradation processes. *Science of the Total Environment*, 963, 178509.
- Gunasekaran, V., Jahnvi, M. P., Sharma, M. H., Shinde, M. P. M., & Babu, C. N. (2025). *A Textbook of Pharmaceutical Inorganic Chemistry*. Shashwat Publication.
- Häder, D. P., Banaszak, A. T., Villafañe, V. E., Narvarte, M. A., González, R. A., & Helbling, E. W. (2020). Anthropogenic pollution of aquatic ecosystems: Emerging problems with global implications. *Science of the Total environment*, 713, 136586.
- Hakam, N., Fuentes, J. L. G., Nabavizadeh, B., Sudhakar, A., Li, K. D., Nicholas, C., ...& Breyer, B. N. (2024). Outcomes in randomized clinical trials testing changes in daily water intake: a systematic review. *JAMA network open*, 7(11), e2447621-e2447621.
- Hakkim, A. H., Kirthiga, S. S., Jain, S. G., Divya, A. M., Raghavan, R., & Gopinath, A. (2024). Nitrates and Phosphates: Boon or Bane for Waterbodies. In *Aquatic Pollution* (pp. 279-289). CRC Press.

- Idowuss, G. A. (2022). Heavy metals research in Nigeria: a review of studies and prioritization of research needs. *Environmental Science and Pollution Research*, 29(44), 65940-65961.
- Intorre, F., Foddai, M. S., & Venneria, E. (2025, April). Unhealthy Dietary Habits and Sedentary Behaviours Among Adolescents and Young Adults in Rome (Italy) Participating in the ALIMA Study: Growing Risks for Health. In *Healthcare* (Vol. 13, No. 9, p. 980). MDPI.
- Jagaba, A. H., Lawal, I. M., Birniwa, A. H., Affam, A. C., Usman, A. K., Soja, U. B., ... & Yaro, N. S. A. (2024). Sources of water contamination by heavy metals. In *Membrane technologies for heavy metal removal from water* (pp. 3-27). CRC Press.
- Jomova, K., Alomar, S. Y., Nepovimova, E., Kuca, K., & Valko, M. (2025). Heavy metals: toxicity and human health effects. *Archives of toxicology*, 99(1), 153-209.
- Kapp, M. N., Baldasso, B., Ghellere, G. J., Porfirio, T. N. S., da Silva, S. S., Ferreira, W., & Boroski, M. (2025). A mobile strategy for water participatory monitoring. *Revista Brasileira de Ciências Ambientais*, 60, e2073-e2073.
- Kaur, M., & Sharma, A. (2021, November). A review on heavy metal accumulation and toxicity in biotic and abiotic components. In *IOP conference series: Earth and environmental science* (Vol. 889, No. 1, p. 012062). IOP Publishing.
- Khalik, I., Ramampandra, E. C., Vorburger, C., Narwani, A., & Schuwirth, N. (2024). The effect of water temperature changes on biological water quality assessment. *Ecological Indicators*, 159, 111652.
- Kondakindi, V. R., Pabbati, R., Erukulla, P., Maddela, N. R., & Prasad, R. (2024). Bioremediation of heavy metals-contaminated sites by microbial extracellular polymeric substances—A critical view. *Environmental Chemistry and Ecotoxicology*, 6, 408-421.
- Lewenstam, A., Migdalski, J., & Filipek, R. (2025). Influence of ionic strength on the ion activity in concentrated mixed sodium hydroxide-strong electrolyte solutions measured by a junctionless galvanic cell without transference. *Sensors and Actuators B: Chemical*, 427, 137206.
- Manimaran, P., Rajaji, U., Chen, S. M., Ramalingam, K. R., Aldossari, S. A., & Liu, T. Y. (2024). Hydrothermal synthesis of rare-earth ferrate for electrochemical detection of 4-aminophenol in food samples and products. *Journal of the Electrochemical Society*, 171(8), 087522.

- Mansor, M. I., Fatehah, M. O., Aziz, H. A., & Wang, L. K. (2024). Occurrence, behaviour and transport of heavy metals from industries in river catchments. In *Industrial waste engineering* (pp. 205-277). Cham: Springer International Publishing.
- Moini, J., & Ferdowsi, K. (2024). Digestion, absorption, and metabolism. In *Handbook of Nutritional Disorders* (pp. 18-42). CRC Press.
- Mukhopadhyay, A., Duttagupta, S., & Mukherjee, A. (2022). Emerging organic contaminants in global community drinking water sources and supply: A review of occurrence, processes and remediation. *Journal of Environmental Chemical Engineering*, 10(3), 107560.
- Nadagouda, M. N., Varshney, G., Varshney, V., & Hejase, C. A. (2024). Recent advances in technologies for phosphate removal and recovery: a review. *ACS environmental Au*, 4(6), 271-291.
- NkueNouwezem, D. J., & Libralato, G. (2021). Integrated Water Resources Management: From Spring to Reuse. In *Clean Water and Sanitation* (pp. 1-13). Cham: Springer International Publishing.
- Oriakpono, O. E., & JAJA, L. (2022). Assessment of Heavy Metal Concentrations in Periwinkle (*Tympanotonus fuscatus*) From Five Creeks of Rivers State, Nigeria. *Journal of Global Agriculture and Ecology*, 14(3), 8-16.
- Orsango, A. Z., Habtu, W., Lejisa, T., Loha, E., Lindtjørn, B., & Engebretsen, I. M. S. (2021). Iron deficiency anemia among children aged 2–5 years in southern Ethiopia: a community-based cross-sectional study. *PeerJ*, 9, e11649.
- Palaka, L., Vijaya Pratap, G., Rao, T. B., Krishna, B., & Keerthana, B. (2025). Assessment of Physico-Chemical Characteristics of Lakshmipuram Lake, Anakapalli Dist., Andhra Pradesh, India. *Tulasi Bhushan and Krishna, Bellala and Keerthana, Bora, Assessment of Physico-Chemical Characteristics of Lakshmipuram Lake, Anakapalli Dist., Andhra Pradesh, India (February 20, 2025)*.
- Pigliasco, F., Cafaro, A., Barco, S., Biondi, M., Stella, M., Mattioli, F., ... & Cangemi, G. (2024). A VAMS- based LC–MS/MS method for precise cenobamate quantification in epilepsy (patients). *Epilepsia Open*, 9(6), 2144-2153.
- Prajapati, A. V., Baxi, N. N., Dave, S. R., & Tipre, D. R. (2024). Mycosorption: a sustainable approach for removing heavy metals from simulated polluted water in non-competitive

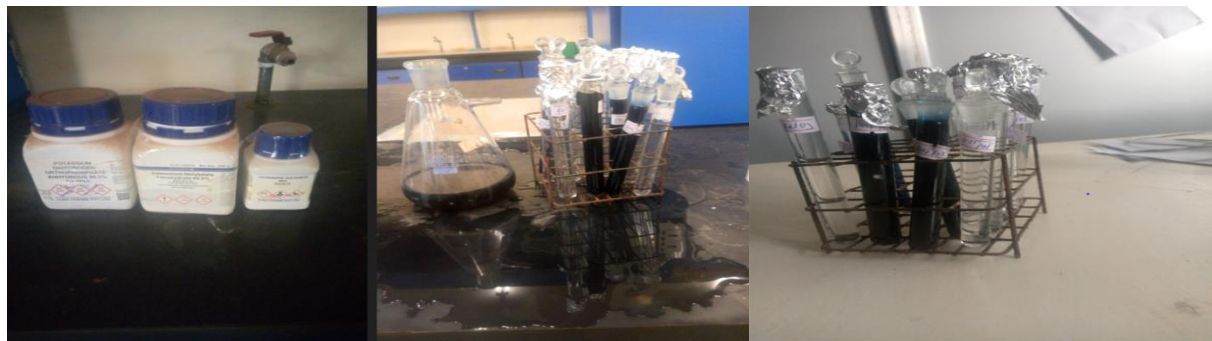
- and competitive systems. *Environment, Development and Sustainability*, 26(12), 31557-31575.
- Pratiwi, Y., Winani, A., & Riyandari, B. A. (2024, January). Analysis of phosphore using ammonium molybdate with thiourea and hydrazine sulphate as reductors by UV-VIS spectrophotometry method. In *AIP Conference Proceedings* (Vol. 2982, No. 1, p. 040021). AIP Publishing LLC.
- Rahimzadeh, M. R., Rahimzadeh, M. R., Kazemi, S., & Moghadamnia, A. A. (2020). Zinc poisoning-symptoms, causes, treatments. *Mini reviews in medicinal chemistry*, 20(15), 1489-1498.
- Raimi, M. O., Ezekwe, C. I., Bowale, A., & Samson, T. K. (2022). Hydrogeochemical and multivariate statistical techniques to trace the sources of ground water contaminants and affecting factors of groundwater pollution in an oil and gas producing wetland in rivers state, Nigeria. *Open Journal of Yangtze Gas and Oil*, 7, 166-202.
- Rajab, N., Ibrahim, H., Zhang, D., Youssef, A. F., & Hassan, R. Y. (2025). Advances in the chemical analysis of nitrite in environmental and biological samples. *Nanoscale Advances*.
- Rathor, P., & Ch, R. (2024). The Impacts of Dietary Intervention on Brain Metabolism and Neurological Disorders: A Narrative Review. *Dietetics*, 3(3), 289-307.
- Ravishankar, H. (2024). *Synthesising novel adsorbent and membranes using Graphene oxide (GO) for removing lead ions from aqueous solutions* (Doctoral dissertation, RMIT University).
- Ruiz-Gonzalez, A. (2024). Ion-selective electrodes in the food industry: Development trends in the potentiometric determination of ionic pollutants. *Electrochem*, 5(2), 178-212.
- Salehi, M. (2025). Surface Complexation at Charged Organic Surfaces. *Reviews in Mineralogy and Geochemistry*, 91(1), 149-173.
- Samanth, M. (2024). A Synopsis of the Role and Significance of the Chemical Elements in Human Body.
- Sanjupriya, S., Poonkothai, M., Karunanidhi, D., Rao, N. S., Subramani, T., & Marghade, D. (2025). Evaluating nitrate contamination in groundwater and its health threats from a

- semi-arid province of southern India using GIS techniques with a special focus on entropy water quality index. *Environmental Geochemistry and Health*, 47(9), 1-26.
- Shah, S. B. (2021). Heavy metals in the marine environment—an overview. *Heavy metals in Scleractinian corals*, 1-26.
- Sharma, S., & Sethi, G. R. (2021). *Standard Treatment Guidelines—A Manual for Medical Therapeutics*, 6e. Wolters Kluwer India Pvt. Ltd..
- Shi, W., Zhang, Z., Li, M., Dong, H., & Li, J. (2024). Reproductive toxicity of PFOA, PFOS and their substitutes: A review based on epidemiological and toxicological evidence. *Environmental Research*, 118485.
- Singh, A., Sharma, A., Verma, R. K., Chopade, R. L., Pandit, P. P., Nagar, V., ... & Sankhla, M. S. (2022). Heavy metal contamination of water and their toxic effect on living organisms. In *the toxicity of environmental pollutants*. IntechOpen.
- Sonone, S. S., Jadhav, S., Sankhla, M. S., & Kumar, R. (2020). Water contamination by heavy metals and their toxic effect on aquaculture and human health through food Chain. *Lett. Appl. NanoBioScience*, 10(2), 2148-2166.
- Tasnim, I. (2025). Quantifying Inositol Phosphate Dephosphorylation to Understand the Role of Recalcitrant Organic Phosphorus Forms on Harmful Algal Blooms in Freshwater Systems.
- Tefera, M. M. (2011). Land-use/land-cover dynamics in Nonno district, central Ethiopia. *Journal of Sustainable development in Africa*, 13(1), 123-141.
- Uddin, M. M., Zakeel, M. C. M., Zavahir, J. S., Marikar, F. M., & Jahan, I. (2021). Heavy metal accumulation in rice and aquatic plants used as human food: A general review. *Toxics*, 9(12), 360.
- Wang, Y., Ju, J., Zhu, W., Liu, Y., Zhang, Y., Kang, W., & Cheng, B. (2024). Water evaporation systems for the simultaneous generation of electricity and water desalination: a review. *Journal of Materials Chemistry A*, 12(37), 24761-24801.
- World Health Organization. (2024). *Guidelines for drinking-water quality: small water supplies*. World Health Organization
- Yazman, M. M., Yüksel, B., Ustaoglu, F., Şen, N., Tepe, Y., & Tokatlı, C. (2024). Investigation of groundwater quality in the Southern Coast of the Black Sea: application of

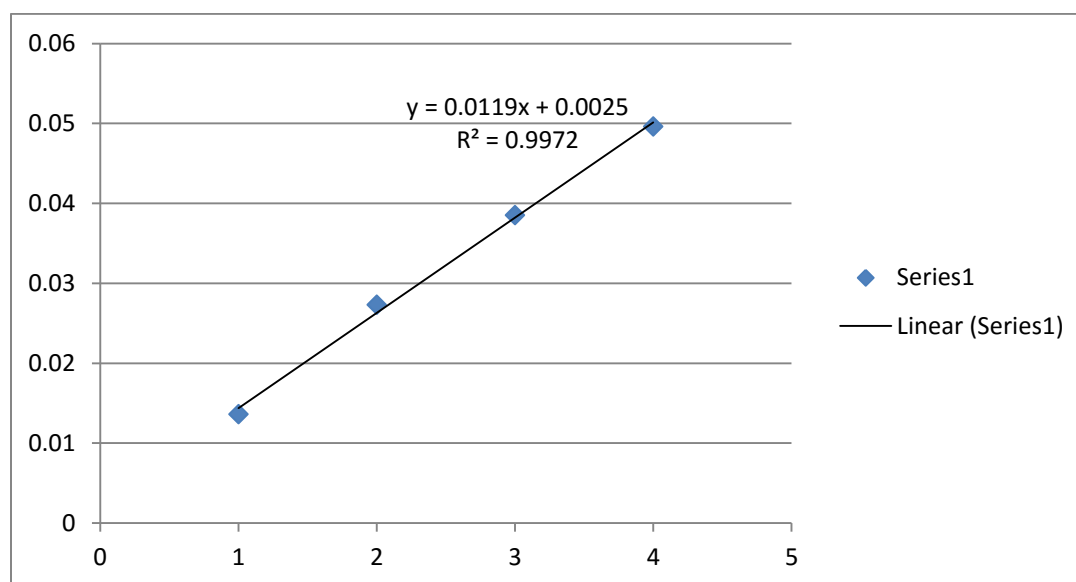
- computational health risk assessment in Giresun, Türkiye. *Environmental Science and Pollution Research*, 31(39), 52306-52325.
- Zahner, L. W. (2020). *Copper, Brass, and Bronze Surfaces: A Guide to Alloys, Finishes, Fabrication, and Maintenance in Architecture and Art*. John Wiley & Sons.
- Zhang, K., Chang, S., Tu, X., Wang, E., Yu, Y., Liu, J., ... & Fu, Q. (2024). Heavy metals in centralized drinking water sources of the Yangtze River: A comprehensive study from a basin-wide perspective. *Journal of Hazardous Materials*, 469, 133936.
- Zoroddu, M. A., Aaseth, J., Crisponi, G., Medici, S., Peana, M., & Nurchi, V. M. (2019). The essential metals for humans: a brief overview. *Journal of inorganic biochemistry*, 195, 120-129.

7. APPENDIX

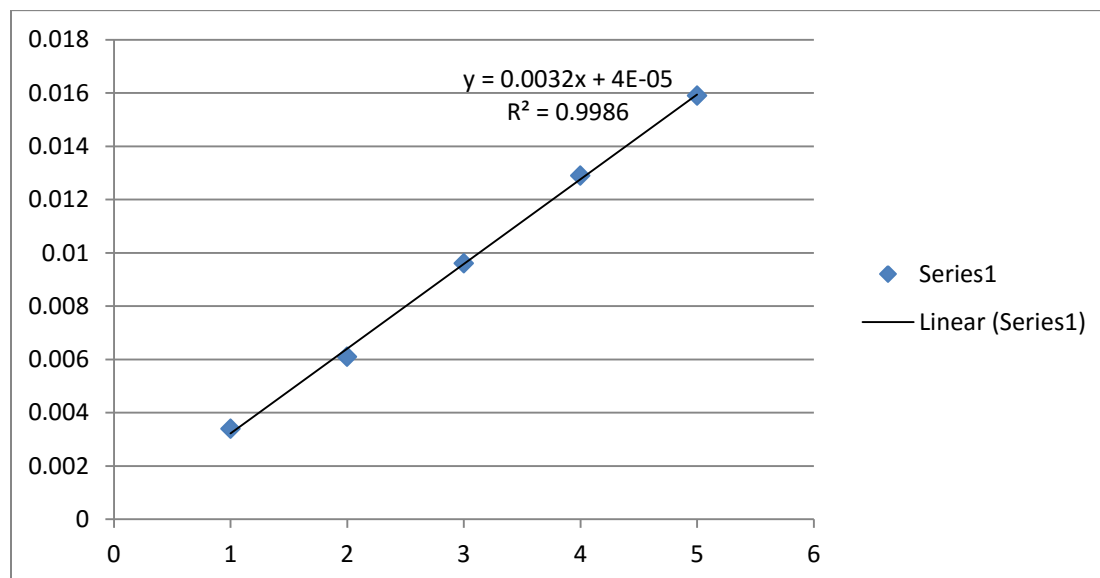
Appendix 1 Figure Nitrate and phosphate ion procedure



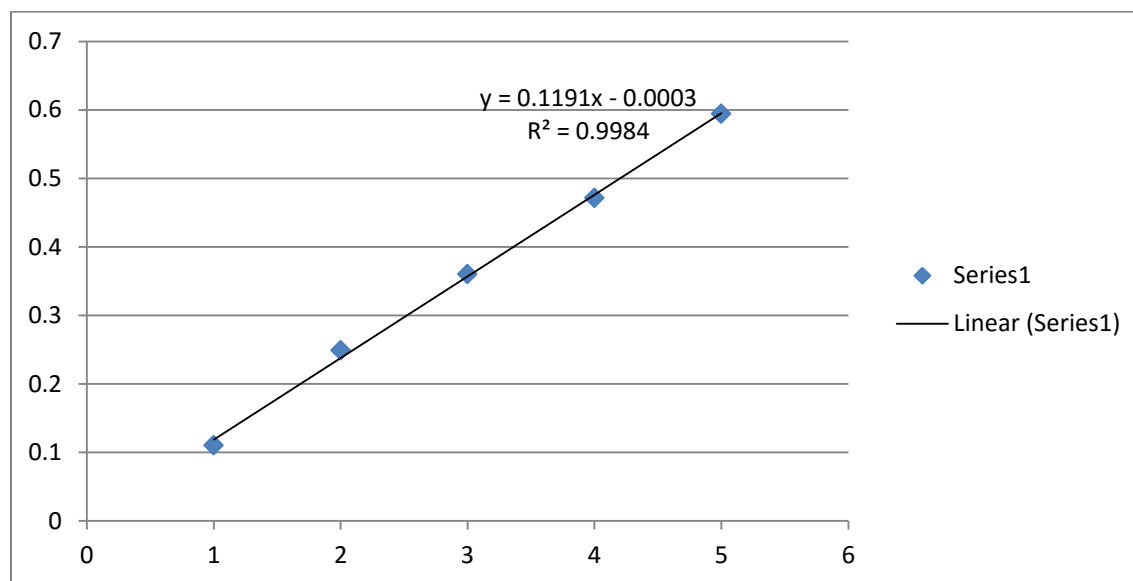
Appendix 2. Concentration versus Absorbance Calibration Curve for Lead



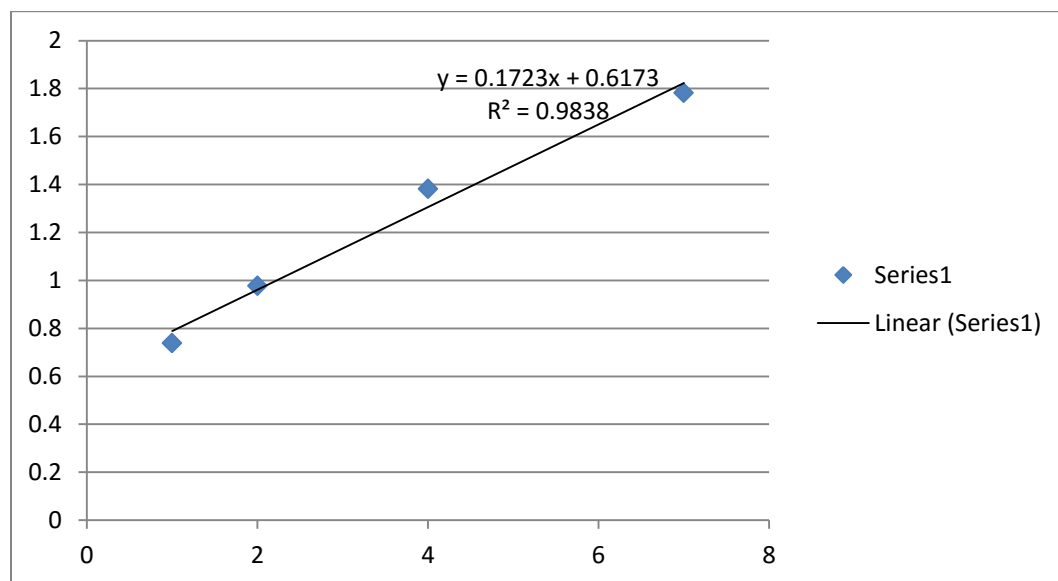
Appendix 3. Concentration versus Absorbance Calibration Curve for Zinc



Appendix 4. Concentration versus Absorbance Calibration Curve for Cadmium



Appendix 5. Concentration versus Absorbance Calibration Curve of Nitrate ion on 220 nm



Appendix 6. Concentration versus Absorbance Calibration curve for phosphate (641nm)

