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SCHOOL OF GRADUATE STUDIES
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M.Sc. THESIS ON

PHYSICO CHEMICAL, BACTERIOLOGICAL AND HEAVY METAL ANALYSIS IN DIFFERENT WATER SOURCES OF YEBU TOWN, JIMMA ZONE, SOUTHWEST ETHIOPIA

BY
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JUNE, 2019
JIMMA, ETHIOPIA

PHYSICOCHEMICAL, BACTERIOLOGICAL AND HEAVY METAL ANALYSIS IN DIFFERENT WATER SOURCES OF YEBU TOWN, JIMMA ZONE, SOUTHWEST ETHIOPIA.

A THESIS PAPER SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES JIMMA UNIVERSITY, COLLEGE OF NATURAL SCIENCES DEPARTMENT OF CHEMISTRY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CHEMISTRY

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DECLARATION

This is to certify that this thesis entitled: **“Physicochemical, Bacteriological and Heavy metal analysis in different water sources of Yebu Town, Jimma Zone, southwest Ethiopia”** submitted to School of Graduate Studies, Department of Chemistry in partial fulfillment for the requirements of Master of Science Degree in Chemistry. I Mesfin Debebe hereby declare that this M.Sc. thesis is my original work and has not been presented for a Degree in any other University and that all source of materials used for the thesis have been duly acknowledged.

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A THESIS PAPER SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES JIMMA UNIVERSITY, COLLEGE OF NATURAL SCIENCES, DEPARTMENT OF CHEMISTRY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CHEMISTRY

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LIST OF ABBREVIATIONS

AAS	Atomic absorption spectrophotometer
ANOVA	Analysis of variance
BOD	Biochemical oxygen demand
CFC	Colony forming unit
COD	Chemical oxygen demand
DO	Dissolved oxygen
EC	Electrical conductivity
EWQG	Ethiopia water quality guideline
GFAAS	Graphite flame atomic absorption spectrophotometer
MF	Membrane filtration
NTU	Nephelometric Turbidity Unit
TC	Total coliforms
TDS	Total dissolved solids
WHO	World Health Organization

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ABSTRACT

Water is a natural resource which forms an essential component of life. The safety of water is important for health. The safety of water is affected by various contaminants which included physico chemical, bacteriological and heavy metal. This study was designed to evaluate the physico-chemical, bacteriological and heavy metal analysis in different water sources of the study area. The study was conducted at Yebu town, Jimma Zone, southwest Ethiopia. Replicated water samples from nine different sampling points were collected using purposive sampling techniques. Analyses of physico-chemical such as dissolved oxygen, biological oxygen demand, nitrate and phosphate, turbidity and electrical conductivities, heavy metals (Cadmium, Lead, Cobalt, Chromium, Copper and Zinc) and bacteriological (Fecal coliform and Total coliform) were conducted following Ethiopian water quality guide lines and WHO (2008). The result of physicochemical parameters were: temperature (ºC) (19.00 ± 0.01 to 23.00 ± 0.49), turbidity (NTU) (4.73 ± 0.01 to 58.70 ± 0.20), pH (5.75 ± 0.04 to 7.60 ± 0.10), EC (µS/cm) (21.30 ± 0.01 to 243.75 ± 0.56) and TDS (0.44 ± 0.05 to 3.75 ± 0.04) mg/ L, DO (4.00 ± 0.01 to 7.16 ± 0.01) mg/ L, total hardness (10.0 ± 0.03 to 189.8 ± 0.20) mg/ L, alkalinity (4.95 ± 0.11 to 159.77 ± 0.65) mg/ L, chloride (1.98 ± 0.01 to 11.97 ± 0.12) mg/ L, nitrate (0.34 ± 0.11 to 4.39 ± 0.04) mg/ L and phosphate (0.42 ± 0.06 to 5.12 ± 0.01) mg/ L, COD (1.18 ± 0.01 to 2.03 ± 0.04) mg/ L, BOD (0.94 ± 0.04 to 1.62 ± 0.03) mg/ L, heavy metals: Cd (0.05 ± 0.01 to 0.06 ± 0.02) mg/L, Pb (0.22 ± 0.10 to 0.32 ± 0.08) mg/L, Co (0.22 ± 0.01 to 0.50 ± 0.03) mg/L, Cr (0.02 ± 0.01 to 0.16 ± 0.05) mg/L, Cu (0.04 ± 0.01 to 0.14 ± 0.02) mg/L and Zn (0.02 ± 0.01 to 0.36 ± 0.06) mg/L and bacteriological (number/100 mL) of Total coliform was 4/100 to 86/100 mL and Fecal coliform 0/100 to 30/100 mL.Turbidity of all water samples from spring and well water, and pH of S06, concentrations of Cd, Pb, Co and Cr of tap, spring and well water, and all total coliforms and fecal coliforms of water samples from T01, T02, T03, S04, W08 and W09 were above the recommended value of EWQG and WHO guide line. In general, consuming water with above of the guideline of the national and international standard could cause serious health problem.

Keywords: Physico-chemical, bacteriological, heavy metal, water sample

1. INTRODUCTION

1.1. Background of the study

Water is a natural resource which forms an essential component of life [1]. However, the suitability of water for various uses depends on the biological and physico-chemical properties of water [2]. Over a 1 billion people lack of access to safe drinking water worldwide [3]. The situation is worst in developing countries like Ethiopia where many people especially the poor have chosen to use the underground water sources like boreholes, springs, shallow wells and rivers as a source of drinking water and for other domestic purpose [4].

Water is the second prerequisite for life next to oxygen [5]. However, majority of the world's population still live without access to healthy water due to continuous contamination with several contaminants such as sewage and industrial effluents [6]. The contamination of water with physical, chemical and microbial contaminants have been posing serious threats to millions of people across the globe.

Clean water is an essential resource for drinking, irrigation, industry, transportation, fishing, support of biodiversity, and recreations. When water becomes polluted, it loses its value economically; aesthetically, and can become a threat to human health, the survival of aquatic organisms and wildlife that depend sources of water available to mankind are: atmospheric water (precipitate), surface water (including rivers, streams, ponds, etc.), and ground water. The groundwater is believed to be comparatively cleaner and free from pollution compared to surface water [7]. But during last decade, it has been observed that groundwater gets polluted drastically because of increased human activities [8]. Consequently, a number of cases of water borne diseases have been seen as the causes of health hazards. Therefore, monitoring the quality of water is one of the essential issues of water management [9]. Groundwater can be contaminated easily in multitude ways, including land application of agricultural chemicals and organic wastes, infiltration of irrigation water, septic tanks, and infiltration of effluent from sewage treatment plants, pits, lagoons and ponds used for storage. Around 94% of the global diarrheal burden and 10% of the total disease burden are due to unsafe drinking water, inadequate sanitation, and poor hygienic practices. Contaminated water serves as a mechanism to transmit communicable diseases such as diarrhea, cholera, dysentery, typhoid and guinea worm infection. WHO, estimates that in 2008 diarrheal disease claimed the lives of 2.5 million people. For children under five, this burden is greater than the combined burden of HIV/AIDS and malaria [10]. Frequent examinations of fecal indicator organisms remain the most sensitive way of assessing the hygienic conditions of water. Fecal coliform has been seen as an indicator of fecal contamination and are commonly used to express microbiological quality of water and as a parameter to estimate disease risk [11].

Prior to 2004, the majority of Ethiopia's population does not have access to safe and reliable sanitation facilities besides insufficient hygienic practices related to food, water and personal hygiene. Accordingly, more than 75% of the health problems in Ethiopia were due to infectious diseases attributed to unsafe and inadequate water supply, and unhygienic waste management, with human excreta being the major problem [12]. Some studies conducted on bacteriological qualities of drinking water in Akaki-Kalit sub-city of Addis Ababa, Ziway, Bahir Dar and Adama towns showed contamination of the water samples with indicator bacteria including total coli forms and fecal coli forms [13]. Besides microbial contaminants of water resources with heavy metals have received particular concern because of their strong toxicity even at lower concentration [14, 15]. Likewise, heavy metals are becoming the cause of water pollution now days. They have relatively high density and are toxic or poisonous at low concentration, because they aree not biologically degradable unlike the case of most organic pollutants, thus easily assimilated and can be bio-accumulated in the protoplasm of aquatic organisms [16]. The common heavy metals include lead, cadmium, chromium, zinc, cobalt and copper could; pose health risk to the consumer and potentially reach through food chain [17].

It could be hypothesized that untreated water could be potential sources of health risk to the local community who heavily rely on those water sources for daily consumption. The risk could be even more pronounced among unprotected water including water from wells and springs. To this effect, this study was designed to evaluate the current safety status of different water sources at Yebu town, Mana Woreda, Jimma Zone, southwest Ethiopia. The water sources included in this study were tap water, springs, and wells. Although theoretically assumed to be safe, tap water samples was collected from point of disinfection, at household levels as well as points of public services to evaluate possible challenges on the route (such as leakage or mix with sewage line) and effect of poor handling at point of services. As majority of the local community rely on alternative water sources.

1.2. Statement of the problem

Water sources such as tap water, spring water and well water of Yebu town, are used for drinking and other purposes. The water quality of these water sources depends on the physico-chemical, biological characteristics of the water. Water bodies could be polluted by addition of foreign materials such as plant and animal matter, domestic sewage, fertilizers, coffee waste, exposure/ contact to human and animal activity. Therefore, assessing the level of these parameters is essential to identify source of any pollution [18]. The toxicity of heavy metals has also long been concerned since it is very important to the health of people and ecology. They accumulate in water at toxic levels as a result of long-term application of untreated wastewaters and cause health problem. The diminishing quality of water seriously delimits its use for human consumption and domestic purposes. Therefore, the continuous and periodical monitoring of water quality is necessary so that appropriate preventive and remedial measures can be undertaken. Also, there are no reports so far in the literature on the study of physico-chemical, bacteriological and heavy metal analysis of tap water, spring and well water supply in the study area. As a result, this study was designed to evaluate the current water quality of tap water, spring water and well water. Accordingly, the study was tried to answer the following research questions.

- Do the physicochemical and bacteriological analysis of the water samples in the study area are within the recommended value of international and national standards?
- Do the heavy metals of the water samples in the study area are within the recommended value of international and national standards?
- Which of the parameter(s) is/are found above the recommended value of international and national standards?

1.3. Objective of the Study

1.3.1. General Objective

The general objective of this study was to investigate the physico-chemical, bacteriological and heavy metals from different water sources of Yebu town, Jimma Zone, southwest Ethiopia.

1.3.2. Specific objectives

- To analyze physical parameters such as pH, temperature and turbidity.
- To analyze the chemical parameters (conductivity, dissolved oxygen, total dissolved solid, total hardness, alkalinity, nitrate, phosphate, chloride, etc.).
- To evaluate the bacteriological (fecal coliforms, total coliforms) in the water samples.
- To determine the concentrations of heavy metals (Cu, Zn, Pb, Cd, Cr, Co) in the water samples.
- To compare the quality of water sources with the recommended value of international and national standards of drinking water.

1.4. Significance of the study

The study of physico-chemical, heavy metals and bacteriological analysis of water samples in the study area could have significance for the community of the study sites in general as well as for the scientific community in particular. Accordingly, the finding of this study could help to know whether the parameters in water samples are within the recommended value of the drinking water and use of other domestic consumption. It could be important for designing appropriate preventive measure to ensure water quality and used as a secondary source of information for further study.

2. LITERATURE REVIEW

2.1. Water quality

The availability of good quality drinking water is extremely important for prevention of diseases and for improving the quality of life for humans since pure water does not exist in nature. Water in its natural form contains living / non-living, soluble / insoluble, organic / inorganic components and its quality keeps on changing from time to time and place to place. The contamination of water is directly linked to the contamination of our environment. Potable water is derived either from surface water (rivers, lakes, streams, ponds etc.). However, water from either source is rarely fit for drinking. It becomes important to measure the quality of drinking water on regular basis to sufficiently support human health and to match WHO standards [19]. The principal objectives of municipal water are the production and the distribution of safe water that is fit for human consumption [20]. A good knowledge of the chemical qualities of raw water is necessary so as to guide its suitability for use. Thus, regular physico-chemical, bacteriological and heavy metals analysis of water at source must be carried out to determine or check the effectiveness of treatment process.

2.2. Physico- chemical parameters

It is very essential and important to test the water before it is used for drinking, domestic, agricultural or industrial purpose. Water must be tested with different physic-chemical and bacteriological parameters. Selection of parameters for testing of water is solely depends upon for what purpose we going to use that water and what extent we need its quality and purity. Water does contain different types of floating, dissolved, suspended and microbiological as well as bacteriological impurities. Some physical test should be performed for testing of its physical appearance such as temperature, color, odour, pH, turbidity, etc, while chemical tests should be performed for its BOD, COD, DO, alkalinity, hardness and other parameters. For obtaining more and more quality and purity water, it should be tested for its trace metal, heavy metal contents and organic i.e. pesticide residue. It is obvious that drinking water should pass these entire tests and it should contain required amount of mineral level. Only in the developed countries all these criteria are strictly monitored [9].

2.2.1. Temperature

Water temperature is important in terms of its effect on aquatic life. For example; it has influence on the solubility of gases, pH, conductivity and planktonic distribution [21]. In an established system the water temperature controls the rate of all chemical reactions, and affects aquatic life such as, reproduction andfish growth. Many aquatic organisms are sensitive to changes in water temperature. Temperature is among the physico-chemical parameters useful in evaluating the quality of drinking water. It influences the overall quality of water (physicochemical and biological characteristics) including the rate of chemical reactions in the water body, decrease in the solubility of gases and improving the tastes and colors of water. However, adverse effect of high temperature may enhance growth of microorganisms and corrosion [22].

2.2.2. pH

pH is an important parameter which is important in evaluating the acid-base balance of water. Also, it is the indicator of acidic or alkaline condition of water status. WHO has recommended maximum permissible limit of pH from 6.5 to 8.5. pH is most important in determining the corrosive nature of water. Lower the pH value, higher is the corrosive nature of water. pH is positively correlated with electrical conductance and total alkalinity [23]. The pH of natural water can provide important information about many chemical and biological processes and provides indirect correlations to a number of different parameters. pH is the measurement of the acid/base activity in solution; specifically, it is the negative common logarithm of the activity/concentration of hydrogen ions; $pH = -\log [H^+]$. pH is typically monitored for assessments of aquatic ecosystem health, recreational waters, irrigation sources and discharges, livestock, drinking water sources, industrial discharges, intakes, and storm water runoff. Adverse effect of high pH imparts taste and soapy feel, while low pH cause corrosion [24].

2.2.3. Electrical conductivity

Electrical conductivity is an estimate of total dissolved salts in water. EC values between 2,500 and 10,000 µS cm^{-1} is not recommended for human consumption and normally not suitable for irrigation except for very salt tolerant crops with special management techniques [25]**.** Conductivity shows significant correlation with various parameters suchas temperature, pH , alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand, chloride and iron concentration of water [26].

2.2.4. Turbidity

Turbidity is caused by particulates in the water and is synonymous with cloudiness. Measured in NTUs [nephelometric turbidity units] or occasionally in JTUs [Jackson turbidity units]. It is significant because excessive turbidity can allow pathogens to hide and, hence, be resistant to disinfection. One of the water treatment operator's primary jobs is controlling turbidity. Turbidity control is usually associated with surface water systems and groundwater systems under the direct influence of surface water. Turbidity or TSS is the material in water that affects the transparency or light scattering of the water. The WHO Guideline for turbidity in drinking water is less than 5 NTU. The turbidity in excess of 5 NTU or 5 JTU may be noticeable and consequently objectionable to the consumers [27].

2.2.5. Dissolved Oxygen

Dissolved oxygen (DO) is an important for many chemical and biological processes taking place in water. DO content of water is influenced by the source, raw water temperature, treatment and chemical or biological processes taking place in the distribution system. Depletion of dissolved oxygen in water supplies can encourage the microbial reduction of nitrate to nitrite and sulfate to sulfide. Dissolved oxygen (DO) is one of the most important parameters for water quality. Its correlation with water body gives direct and indirect information; for example, it has relation with bacterial activity, photosynthesis, availability of nutrients, stratification of lakes and etc [28]. DO is essential to all forms of aquatic life including the organisms that break down man-made pollutants. Oxygen is soluble in water and the oxygen that is dissolved in water will equilibrate with the oxygen in atmosphere. Oxygen tends to be less soluble as temperature increases. The DO of fresh water at sea level will range from 15 mg/L at 0°C to 8 mg/L at 25°C. Concentrations of unpolluted fresh water will be close to 10 mg/L.

In waters contaminated with fertilizers, suspended material, or petroleum waste, microorganisms such as bacteria will break down the contaminants. The oxygen will be consumed and the water will become anaerobic. Typically DO levels less than 2 mg/L will kill fish [29]. Dissolved oxygen in water can decrease due to microbial activity, respiratory and organic decay. Adverse effect of low DO encourages for anaerobic reaction and formation of NO_2, H_2S giving rise to odor.

2.2.6. Total hardness

The most desirable range of hardness is between 80 and 100 mg/L. A total hardness of less than 80 mg/L may result in corrosive water, while hardness above 100 mg/L may result in the need for more soap during bathing and laundering. Excessive hardness may also lead to scale deposits in pipes, heaters, and boilers [30].

2.2.7. Alkalinity

It is composed primarily of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-), alkalinity acts as a stabilizer for pH. Alkalinity, pH and hardness affect the toxicity of many substances in the water. Poorly-buffered water will have a low or very low alkalinity and will be susceptible to pH reduction by, for example, "acid rain"[31]. To maintain a fairly constant pH in a water body, a higher alkalinity is preferable. High alkalinity means that the water body has the ability to neutralize acidic pollution from rainfall or basic inputs from waste water [33].

2.2.8. Total dissolved solids

Dissolved solids and total dissolved solids are terms generally associated with freshwater systems and consist of inorganic salts, and dissolved materials**.** The principal inorganic anions dissolved in water include the carbonates, chlorides, sulfates, and nitrates (principally in ground waters); the principal cations are sodium, potassium, calcium, and magnesium. Excess dissolved solids are objectionable in drinking water because of possible physiological effects, unpalatable mineral tastes, and higher costs because of corrosion or the necessity for additional treatment. The physiological effects directly related dissolved solids include laxative effects principally from sodium sulfate and magnesium sulfate. The adverse effect of sodium on certain patients afflicted with cardiac disease and women with toxemia associated with pregnancy and also undesirable taste [24].

2.2.9. Phosphate

Phosphates will form salts with sodium and calcium and fall out of solution to accumulate in the sediment. In general, phosphates are not very toxic to people or other living organisms. Like nitrogen containing compounds, the main environmental impact associated with phosphate pollution is eutrophication. High levels of phosphorus will be quickly consumed by plant and microorganisms, impairing the water by depleting the dissolved oxygen and increasing the turbidities. These impairments will kill or harm fish and other aquatic organisms [24].

2.2.10. Chloride

Chloride anions are usually present in natural waters. High chloride content may indicate pollution by sewage or industrial wastes or by the intrusion of seawater or saline water into a freshwater body or aquifer. A salty taste in water depends on the ions with which the chlorides are associated. With sodium ions the taste is detectable at about 250 mg/L Cl^-, but with calcium or magnesium the taste may be undetectable at 1,000 mg/L. Chloride is very common and occurs in human, animal and industrial wastes. However, the most common type of water in which chloride dominates have high sodium content [32]. High chloride content has also a corrosive effect on metal pipes and structures and is harmful to most plants and also undesirable taste [33].

2.2.11. Nitrate

Nitrate ion is the common form of nitrogen in natural waters. Nitrite (NO_2^-) will oxidize into nitrate after entering an aerobic regime; $NO_2^- + H_2O \rightleftharpoons NO_3^- + 2H^+$. Similarly, plants and microorganisms will reduce nitrate into nitrite but nitrite ion will quickly oxidize back into nitrate once it reenters the water. Natural sources of nitrate are igneous rock, plant decay and animal debris. Nitrate levels over 5 mg/L in natural waters normally indicates man made pollution, 200 mg/L is an extreme level. Man made sources include, fertilizers, livestock, urban runoff, septic tanks, and waste water discharges. In general, nitrates are less toxic to people than ammonia or nitrite. Methemoglobinemia is nitrate poisoning where high levels of nitrate enter in hemoglobin will oxidize the iron II into iron III inhibiting the blood's ability to carry oxygen and suspect of certain form of cancer risk. In adults it is less effective due to nitrate metabolizing triglycerides present at higher concentration [19].

In the environment, nitrate will become toxic to fish at about 30 mg/L. Nitrate pollution will cause eutrophication of a stream where algae and aquatic plant growth will consume the oxygen and increase the TSS of the water. Eutrophication is usually the result of nitrate and phosphate contamination and is a significant reduction of water quality. Nitrate can exist naturally in groundwater but can increase dramatically on irrigated lands if the irrigation operation is not managed properly. Groundwater contaminated with nitrate can contaminate sources of drinking water in wells. This will contaminate the surface water as the ground water recharges streams and lakes. As more land is converted into agricultural land and as urban areas expand, nitrate monitoring is an important tool in accessing, locating and mitigating man made sources of nitrate [34].

2.2.12. Biochemical oxygen demand

Biochemical oxygen demand **(**BOD**)** is the oxygen required for the microorganism to perform biological decomposition of dissolved solids or organic matter in the waste water under aerobic conditions [35]. BOD is a measure of organic material contamination in water, specified in mg/L; typically, the test for BOD is conducted over a five-day period.

2.2.13. Chemical oxygen demand

Chemical oxygen demand (COD) is another measure of organic material contamination in water specified in mg/L. COD is the amount of dissolved oxygen required to cause chemical oxidation of the organic material in water. Both BOD and COD are key indicators of the environmental health of a surface water supply. They are commonly used in waste water treatment but rarely in general water treatment. COD provides a measure of the oxygen equivalent of that portion of the organic matter in a water sample that is susceptible to oxidation under the conditions of the test. It is an important and rapidly measured variable for characterizing water bodies, sewage, industrial wastes and treatment plant effluents [33].

2.3. Heavy metals and their toxicity

Heavy metals are elements having atomic weights between 6.5 and 200.6 and a specific gravity more than 5.0 g/cm^3 [36]. Some heavy metals are toxic or carcinogenic, and are not biodegradable and tend to accumulate in living organisms [37]. Small amounts of heavy metals are common in our environment and diet. They are actually necessary for good health, but when natural water bodies are contaminated with wastewater containing higher concentration of heavy metals; it affects aquatic life and is destructive to the environment. Bioaccumulations of heavy metals in the body through food chain lead to a variety of incurable diseases when people drink the water or eat the food contaminated by heavy metals [38]. Some heavy metals *viz*. copper, iron, and zinc are required in trace amount by living organisms. However, they can be detrimental to the organism when they are in excessive level. Non-essential heavy metals of particular concern to surface water systems are cadmium, and lead [38]. Heavy metal can enter surface or ground water through natural sources, industrial sewage, and leakage from urban or agricultural areas, water pipes walls or even from domestic sources. Examples of heavy metals included in this study are: Cadmium, Chromium, Cobalt, Copper, Lead, and Zinc.

2.3.1 Lead (Pb)

Lead is considered as one of the most dangerously toxic heavy metals because it is ubiquitous metal which is present everywhere including homes, soil, work place, foods and water [39]. The main sources of pollution of natural water by lead are lead pipes, mines and effluent of many industries such as those producing batteries, automobiles, metal sheets garages or paint. Lead may enter the atmosphere during mining, smelting, refining, manufacturing processes and by the use of lead products. Lead intake occurs from the consumption of whisky, fruit juices, food stored in lead containers, cosmetics, cigarettes and motor vehicle exhaust [40]. Lead may occur in drinking water either by contamination of the source water used by the water system, or by corrosion of lead plumbing. The WHO guideline about drinking water for human consumption states that the maximum allowed lead concentration in drinking water should not exceed 0.01 mg/L and some precautions can be taken to lower lead content in drinking water. Health effect of Lead is toxic to both the central and peripheral nervous systems [41].

2.3.2 Cadmium (Cd)

Cadmium is recovered as a by-product from the mining of sulfide ores of lead, zinc and copper. Cadmium compounds are used as stabilizers in PVC products, color pigment, several alloys and now most commonly, in re-chargeable nickel– cadmium batteries and present as a pollutant in phosphate fertilizers. Cadmium is a highly toxic heavy metal, considered carcinogen. Cadmium exposure may cause kidney damage. Its harmful action is similar to the effect of lead and it can be released in drinking water by zinc and iron pipes. Zinc always contains a small amount of cadmium. Cadmium occurs naturally in zinc, lead, copper and other ores which act as source to ground and surface waters. Cadmium can be released in drinking water from the corrosion of some galvanized plumbing and water main pipe material [42]

2.3.3 Chromium (Cr)

Chromium does not occur freely in nature. Chromium compounds can be found in water only in small amount. Chromium and its compounds can be discharged into drinking water through erosion, atmospheric precipitation, geochemical source and effluents [43]. When inhaled chromium compounds are irritates, resulting in airway irritation, lung, and nasal or sinus cancer. The health hazards associated with exposure to chromium are dependent on its oxidation state. The metal form is low toxicity. The hexavalent form is toxic. Adverse effects of the hexavalent form on the skin may include ulcerations, allergic skin reactions and carcinogenicity suspect of chromium (VI) compounds.

2.3.4 Copper (Cu)

Copper occurs naturally in ores. It is mined as a primary ore product from copper sulfide and oxide ores. It is released into the environment through mining, agriculture and industrial activities. Copper is used extensively in the manufacture of textiles, antifouling paints, electrical conductors, plumbing fixtures, pipes, coins, cooking utensils, wood preservatives, pesticides and fungicides, and copper sulfate fertilizers. The mobility of copper in soil depends on the soil pH and the content of organic compounds and other minerals with which copper might interact. In general, copper has low mobility in plants relative to other elements. Sensitivity to the toxic effects of excess dietary copper is influenced by its chemical form, species, and interaction with other dietary minerals. High levels can cause symptoms of acute toxicity, including nausea, abdominal discomfort, diarrhea, hemoglobinuria and/or hematuria, jaundice, oliguria/anuria, hypotension, coma and death. Histopathological effects have been observed in the gastrointestinal tract, liver and kidney. Effects on thyroid and particularly the nervous system on long -term exposure occurred. There is limited information on chronic copper toxicity. However, copper does not appear to be a cumulative toxic hazard for man, except for individuals suffering from Wilson’s disease. Copper is not considered to be mutagenic, carcinogenic or affect reproduction [44].

2.3.5 Zinc (Zn)

Zinc is a ubiquitous metal present in the environment, most rocks and many minerals contain zinc which can be used for the zinc industry. Natural emissions results from erosion and forest fires. Anthropogenic sources are mining, zinc production facilities, iron and steel production, corrosion of galvanized structures, coal and fuel combustion, waste disposal and the use of zinc-containing fertilizers and pesticides. Zinc is utilized as protective coating of other metals, dye casting, construction industry, for alloys, dry cell batteries, dental, medical and household applications, fungicide, topical antibiotics and lubricant [44]. Zinc is an essential nutrient for body growth and development; however, drinking water containing high levels of zinc can lead to stomach cramps, nausea and vomiting. Water with a zinc concentration of more than 5 mg/L may start to be become chalky in appearance with a detectable deterioration in taste.

2.3.6 Cobalt (Co)

Cobalt is a trace metal element which is essential for normal cellular metabolism but at high levels may lead to reduce human osteoblast activity, changes in osteo protegrin (OPG)/receptor activator of nuclear factor kappa Brigand (RANKL) ratio leading to oxidative DNA damage, cellular apoptosis, necrosis, and oxidative DNA damage. Subsequently, elevated cobalt levels can elicit a multitude of symptoms including cardiomyopathy, hypothyroidism, polycythemia, cognitive dysfunction, neuropathy, and fatigue [45].

2.4. Bacteriological water quality

The Bacteriological quality of drinking water is determined by tests for total coliform (which includes E. coli and fecal coliforms). These organisms are found in the intestinal tract of warm-blooded animals and in soil. Fecal coliforms and E. coliforms come from human and animal fecal waste.

2.4.1. Fecal coliforms (FC)

Fecal coliforms are one of the most important parameters to consider when assessing the suitability of drinking water because of the infectious disease risk. Fecal coliforms indicate contamination by mammals and birds' waste (faces) and signify the possible presence of pathogenic bacteria and viruses. They are responsible for water-related diseases such as cholera, typhoid and other diarrheal-related illnesses. One gram of faces is reported to contain 10,000,000 viruses; 1,000,000 bacteria; 1000 parasite cysts; and 100 parasite eggs. Zero fecal cfu/100 mL is considered uncontaminated in drinking water [46].

2.4.2. Total coliforms (TC)

Total coliform group of bacteria is unreliable indicators of fecal contamination because many members are capable of growth and long-term persistence (having a non-fecal origin) in many environments, including water distribution systems. On the other hand, there are more TC bacteria in untreated fecal waste than any of the other fecal indicators or indicator groups, making the TC test the most sensitive of all indicator tests. Because of this sensitivity, the TCR (total coliform rule) relies on the TC bacteria test as the initial test to detect the possible presence of fecal contamination in delivered water, as well as to assess water treatment effectiveness and the integrity of the distribution system. The most commonly measured indicators of water quality are the coliform organisms. Gram negative bacteria are cytochrome oxidate negative, non-spore forming, and ferment lactose at 35^{o}C – 37^{o}C, within 24 – 48 hours [47]. Thus, the total coliform group should not be regarded an indicator of organisms exclusively from fecal origins especially in hot countries where coliforms of non-fecal origins are common. In the presence of organic material and under suitable conditions, coliforms multiply. Measurement of fecal coliforms is a better indicator of general contamination of fecal origin. Fecal coliforms differ from the other members of the total coliform groups on the grounds that they tolerate and grow at higher temperatures of 44 - 45^{o}C [48].

3. MATERIALS AND METHODS

3.1. Study area and period

The study was conducted at Yebu town, Mana Woreda, Jimma Zone, southwest Ethiopia. Yebu is located about 364 km southwest of Addis Ababa, and 18 km West of Jimma Town, Geographically, the town is located 7°46’59.99” N latitudes, 36°43’59.99” E longitude and altitude that range from 1914 to 1940 m above sea level. The study was conducted from July 2018 to June 2019.

Table 1: Specific sampling sites of the water source, Yebu town, September, 2018

Sampling site of water source	Sampling site Code	Altitude (Elevation(m))	GPS location of sampling site	
			Latitude (North direction)	Longitude (East direction)
Tap water (Yechamo source)	T01	1915	7^{o}46’970’’	36^{o}43’573’’
Tap water (around health center)	T02	1935	7^{o}46’462’’	36^{o} 43’527’’
Tap water (Bus station sefer)	T03	1940	7^{o}46’029’’	36^{o}43’547”
Unprotected spring water around TVET	S04	1939	7^{o}46’378’’	36^{o}43’531”
Spring water (Awalani)	S05	1914	7^{o}46’471’’	36^{o}42’430”
Unprotected spring water (Abdela meda)	S06	1918	7^{o}46’988’’	36^{o}43’550”
Protected well water (around health center)	W07	1917	7^{o}46’922”	36^{o}43’557”
Aba Diga protected well water	W08	1916	7^{o}46’791”	36^{o}43’791”
Goma ber unprotected well water	W09	1929	7^{o}46’999”	36^{o}43’557”

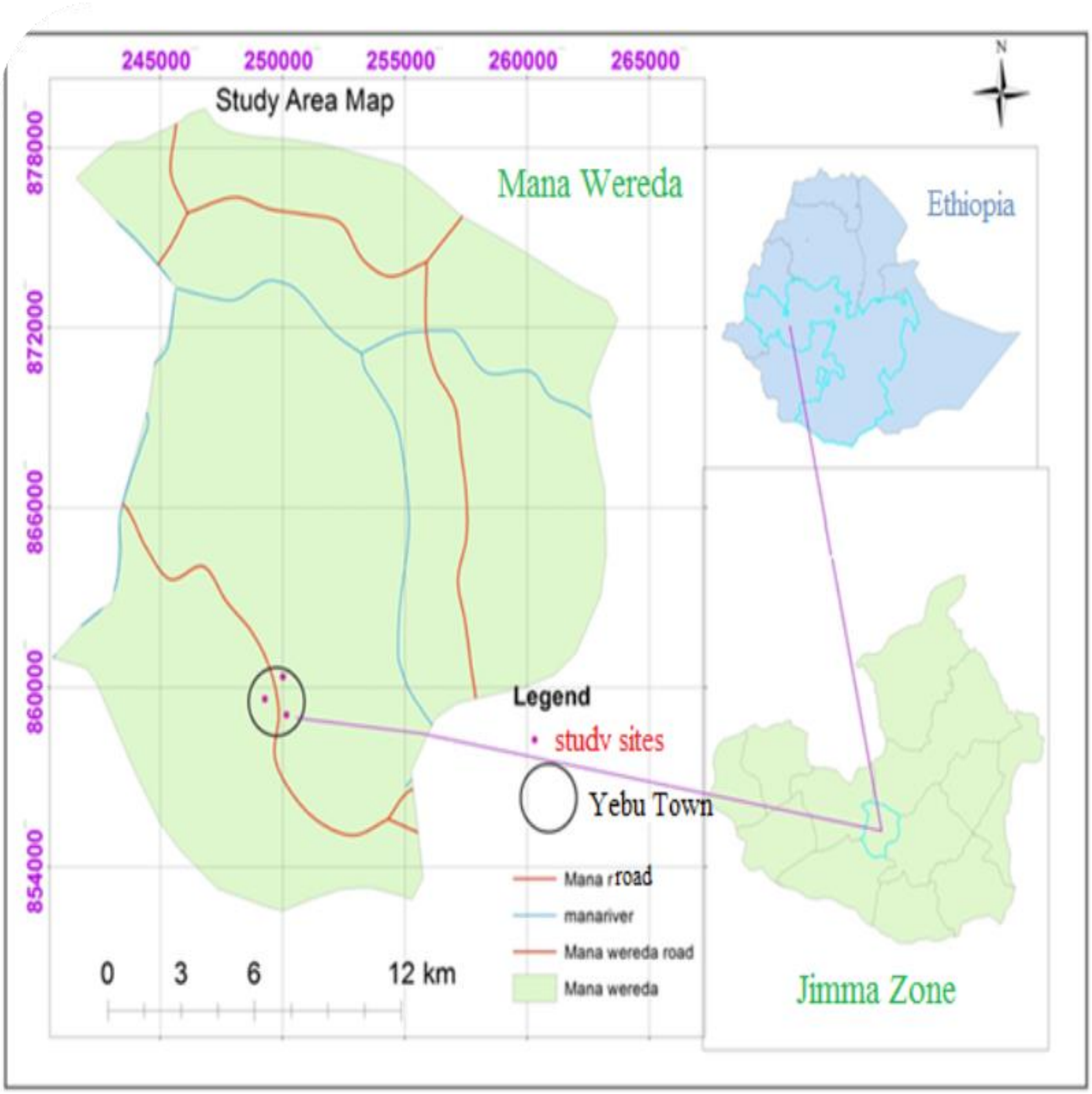

Figure 1: Map of the study sites, Yebu town, Mana Wereda, Jimma, southwest Ethiopia

3.2. Selection of study area

The communities of Yebu town uses tap water, spring water and well water for drinking and other domestic purposes. However, the possible contamination of these water sources by animal faces, soil erosion, coffee and domestic waste could make the water to be polluted and cause health problems to consumer. As a result, this study site is selected for analyzing the water quality status of the samples.

3.3. Sampling and sampling strategies

The sample for the tap water was taken from locations that are representative of the water source, treatment plant, storage facilities, distribution network, points at which water is delivered to the consumer as cited by related literatures [17]. For well and spring water, the sampling sites were selected after taking into consideration different factors; such as geographical location, weather condition and possible contamination sources. Accordingly, purposivesampling techniques were used for the collection of water samples from each sampling sites. Replicated total 9 water samples were collected from three different water sources including tap water (n = 3), spring water (n = 3), well water (n = 3). Based on the standard procedure, parameters such as: temperature, conductivity, turbidity, dissolved oxygen and pH was measured on site.

3.4. Sampling and preservation

Water samples was taken by polyethylene bottles. The sampling bottles were kept overnight in a 10% HNO_3 solution and then repeatedly washed with distilled water and dried in an oven for 24 h before use. Standard methods were used prior to taking water samples in which sampling bottles were rinsed with distilled water and the water samples being collected. Immediately as the water sample was collected, acidified with 2 mL concentrated HNO_3. Sampling bottles was labeled to indicate sampling site and date of sampling. The collected water samples were transported to laboratory in ice box and kept in refrigerator below 4^{o}C until analysis time.

3.5. Chemicals and reagents

All the chemicals and reagents used were of analytical grade: HNO_3 (65%) (uni chem, N43725), HCl (37%), Pb $(NO_3)_2$, Cr $(NO_3)_2$, Zn $(NO_3)_2$, Cu $(NO_3)_2$, Co $(NO_3)_2$, Cd $(NO_3)_2$ all are stock solution of 1000 mg/L and distilled water was used for solution preparation, dilution and rinsing purposes.

3.6. Apparatus and instruments

Different sized volumetric flasks, burette, beakers, measuring cylinders, filter funnel, desiccators, petri dishes, polyethylene bottle, sterile glass bottles, digital conductivity meter, DO meter, pH meter, ice bag , refrigerator, drying oven, , analytical balance, UV-Vis, microwave digestion (Top Wave, analytikjena , Germany), qualitative filter paper 20-25µ pores size Ø9 cm with vacuum filtration set up, Membrane Filter, AAS (GFAAS NOVAA 400P, analytikjena, Germany) were used during the study.

3.7. Sample preparation and analysis

3.7.1. Water sample preparation and analysis for selected physicochemical parameters

Chemical parameters such as, nitrate and phosphate of the water samples were determined using UV-Visible spectrophotometer. Total hardness and total alkalinity were determined by titration method. These samples were analyzed at research laboratories of Department of Chemistry, and Department of Environmental Health Science and Technology, Jimma University.

3.7.2. Digestion of water samples for metal analysis

Selected heavy metals such as Cu, Zn, Cd, Pb, Co and Cr were analyzed at Arba Minch University, Chemistry laboratory. For the analysis, 20 mL of water sample was mixed with 8 mL (3:1) concentrated HNO_3 and HCl in Teflon tube and digested in microwave for 30 minutes between 150-180 ^{0}C and pressure 10-15 atm. Then after cooled the resulting digest was filtered to remove some insoluble particles using qualitative filter paper. The filtrate was transferred into 100 mL volumetric flask and adjusted to 100 mL with distilled water. Corresponding blank samples were digested in the same manner. Finally, the concentration of each heavy metal analyte was measured using GFAAS.

3.7.3. Water sample preparation and analysis for bacteriological quality

Data collection for bacteriological water samples were according to WHO guideline of membrane filtration methods using sterilized bottle. The samples were transported to analyze by Membrane Filter Technique at Environmental Health Science and Technology Laboratory, Jimma University. This technique involves filtering a known volume (100 mL) for drinking water samples of water through a special sterile filter. These filters are made of nitrocellulose acetate or polycarbonate, are 150 µm thick, and have 0.45 µm diameter pores. A grid pattern is typically printed on these filter disks in order to facilitate colony counting. When the water sample is filtered, bacteria (larger than 0.45 μm) in the sample are trapped on the surface of the filter. The filter is then carefully removed, placed in a sterile petri plate on a pad saturated with a liquid or agar-based medium, and incubated for 24 hours at 44.5°C. It is assumed that each bacterium trapped on the filter was then grows into a separate colony by counting the colonies one can directly determine the number of bacteria in the water sample that was filtered [49].

The drinking water standard for coliform bacteria in water should be zero. Public water systems are required to test regularly for coliform bacteria. For example; private system testing will be done at the owner's discretion. Accordingly, drinking water from a private system should be tested for biological quality at least once each year, usually in the spring.

3.8. Method of validation

3.8.1. Determination of detection limits

The detection limit of an individual analytical procedure is the lowest amount of analyte sample which can be detected but not necessarily quantitated as an exact value. Method detection limit is defined as the minimum concentration of analyte that can be measured and reported with 99% confidence that the analyte concentration is greater than zero [50]. In other words, it is the lowest analyte concentration that can be distinguished from statistical fluctuations in a blank, which usually correspond to three times the standard deviation of the blank δ blank where δ standard deviation of the blanks and added the mean of the blanks [50]. Five blank samples were digested following the same procedure as the samples and each of the blank samples was analyzed for the selected heavy metals (Zn, Cd, Cr, Cu, Co and Pb). The standard deviation for each metal was calculated from the five blank measurements and the mean to determine method detection limit of the instrument [51]. Limit of detection (LOD) is based on the standard deviation of the response and the slope.

The detection limit (LOD) expressed as: **LOD = 3 σ/S**

Where: δ = standard deviation of five blank samples

S = the slope of the calibration curve

3.8.2. Determination of quantification limits

The quantitation limit of an individual analytical procedure is the lowest amount of analyte in a sample which can be quantitatively determined with suitable precision and accuracy. Limit of quantitation (or limit of determination) is the lowest concentration of the analyte that can be measured in the sample matrix at an acceptable level of precision and accuracy. However, in the absence of specified precision, the limit of quantification is the same as the concentration that gives a signal 10 times the standard deviation of the blank [52]. Limit of quantization is the lowest limit for precise quantitative measurements [53]. The quantization limit of each element will be calculated as ten times the standard deviation of the blank (10σblank, n = 5).

The quantization limit (LOQ) may be expressed as: **LOQ = 10 σ/S**

where: σ = the standard deviation of the sample blank

S = the slope of the calibration curve

3.8.3 Instrument calibration Curve

Calibration curves were prepared to determine the concentration of heavy metal. Analytical grade of stock solutions containing 1000 mg/L of each metal was purchased and used for the preparation of working standard solutions. Standard solutions for all metals were prepared from the stock solutions by serial dilutions. Distilled water was used for solution preparation and dilution purpose. The concentration of Cu, Zn, Cd, Pb, Co and Cr in the solution was analyzed using GFAAS.

3.8.4. Precision and accuracy

Accuracy and precision are probably the most often quoted terms to express the extent of errors in a given analytical results. Analytical results must be evaluated to decide on the best values to report and to attempt to establish the probable limits of errors of these values [54, 55]. The analyst was concerned with the question of precision (repeatability of results), that is, the agreement between a set of results for the same quantity; and also, with accuracy, that is the difference between the measured value and the true value of the quantity, which is determined [55].

3.8.4.1 Accuracy

Accuracy is the closeness of an individual test result to the true value. The accuracy and validity of the measurement was determined by analyzing spiked samples. Triplicate samples were prepared and triplicate readings was taken. The analytical accuracy of the procedures was determined by spiking experiment. The percentage recovery of each data was calculated.

3.8.4.2 Recovery Test

One of the most important quality assessment tools is testing the recovery of a known addition or spike of analyte to a method blank, field blank or sample. In situations where of standard reference materials are not available it is common practice to perform spiking experiment to evaluate the efficiency of a wave digestion method. Performance of the selected digestion method for water sample measured by conducting recovery test on spiked samples using composite standard solution of the analyzed metals. Percent recovery for the metals was calculated using the following equation: -

$$\text{Percent recovery} = \frac{C - C_O}{C_A} \times 100$$

where: - R- percent recovery.

C- measured concentration of a metal in the spiked sample.

Co- Average concentration of the metals in the samples water

C_A- Concentration equivalent added to the spiked sample

3.8.4.3 Precision

It is the closeness of agreement (degree of scatter) between a series of measurements. In this study the precision of the results were evaluated by the standard deviation of the results of triplicate samples (n = 3), analyzed under the same condition. Standard deviation is a useful parameter in estimating and reporting the probable size of indeterminate errors. An acceptable level of precision is typically 10 to 20% of relative standard deviation depending upon the concentration level measured. The precision of the results was evaluated by percentage of relative standard deviation of the results. %RSD range of result from 5 - 15%

3.9. Data analysis

Data were analyzed using SPSS statistical software (version 25) and MS Excel. Results of physico-chemical analysis, heavy metals (Mean ± SD) and microbial counts of the investigated water samples were compared with the set standards (EWQG and WHO guide lines for drinking water quality) and interpreted as acceptable or unacceptable. Mean variation between samples were computed using one-way ANOVA. The parameters were correlated against each other to determine their relationship using Pearson's correlation. In all cases, significance was considered at 95 % confidence interval.

4. RE SULTS AND DISCUSSION

4.1. Result of Method Validation

The efficiency of the method used was evaluated by determination of LOD and LOQ as well as performing recovery studies. The LOD and LOQ can be determined experimentally by running blank samples as discussed above and their value were given in Table 2 This was done to determine whether the blank sample contributes measurable quantities of the metals to be analyzed or contamination is introduced during the digestion.

Table 2: Method detection and quantification limits for tap, spring and well water samples.

Metal	IDL (mg/L)	LOD (mg/L)	LOQ (mg/L)
Cu	0.0001	0.01960	0.05136
Zn	0.0001	0.02716	0.045721
Cd	0.000075	0.0358	0.05196
Pb	0.0003	0.0224	0.05416
Co	0.000001	0.03779	0.046334
Cr	0.000005	0.02978	0.04928

IDL = Instrument detection limit; LOD = limit of detection and LOQ = Limit of quantification

In this case, the value of method detection limit of each element's become more or less high than that of the instrumental detection limit but it is lower than the minimum working standard solution used for the calibration curve. This confirms that the method was good and acceptable. Likewise, the limit of quantization was greater than the limit of detection and less than the lowest working standard solution.

4.2. Recovery Studies

In this study, the accuracy of the method was evaluated by recovery studies. To perform a recovery study, a known amount of analyte was added into water samples as shown in Table 3.

Table 3: Percent recovery of metal analyte

Analyte	Unspiked (mg/L)	Spiked (mg/L)	Added (mg/L)	% Recovery
Cu	0.04	1.87	2	91.5
Zn	0.21	2.55	2	116
Cd	0.06	2.07	2	100
Pd	0.31	2.66	2	117
Co	0.22	2.42	2	110
Cr	0.07	2.40	2	116

From the Table 3: the percentage recovery values were nearly quantitative and in the acceptable range (80 – 120%) for the digestion method.

4.3. Physico-chemical analysis of water samples

Water quality refers to the chemical, physical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need. Hence physicochemical parameter study is very important to get exact idea about the quality of water and to compare results of different physicochemical parameter values with standard values. The physico-chemical characteristics of water samples from different water source at the study site are presented in Table 4.

Table 4: Mean of physico-chemical parameters (Mean ± SD; n=3) of water samples

Physicochemical parameters	Water samples									WHO guide line (2008)	EWQG Limit (2010)
	T*01	T02	T03	S*04	S05	S06	W*07	W08	W09		
Temperature (°C)	22.90±0.01	22.40±0.02	20.10±0.02	21.70±0.01	20.80±0.01	23.00±0.49	23.00±0.49	21.80±0.01	19.00±0.01	25-30	-
Turbidity (NTU)	4.76±0.01	4.73±0.01	4.72±0.02	22.50±0.21	12.09±0.02	10.83±0.22	6.52±0.01	5.70±0.01	58.70±0.20	5	5
TDS (mg/L)	1.12±0.09	1.13±0.06	0.44±0.41	0.90±0.01	1.08±0.06	3.75±0.04	0.97±0.04	0.44±0.05	1.28±0.01	500	500
Electrical conductivity (EC)µScm^{-1}	243.56±0.58	243.53±0.04	243.75±0.56	53.13±0.57	54.93±0.02	54.40±0.31	21.30±0.01	64.60±0.01	52.64±0.57	300	800
Dissolved oxygen (DO) (mg/L)	6.70±0.09	7.12±0.00	7.16±0.01	5.82±0.03	4.91±0.02	4.60±0.20	4.00±0.01	4.51±0.23	7.06±0.01	8	10
pH	7.60±0.10	7.40±0.09	7.40±0.09	6.40±0.02	6.80±0.09	5.75±0.04	6.17±0.01	6.00±0.02	6.90±0.02	6.5-8.5	6.5-8.5
Total hardness (TH) (mg/L)	179.9±0.29	168.0±0.19	189.8±0.20	10.0±0.03	11.1±0.05	19.00±0.05	123.9±0.09	70.4±0.53	34.3±0.61	500	500
Total alkalinity (TA) (mg/L)	152.34±0.57	153.97±0.15	159.77±0.65	11.98±0.06	14.31±0.57	4.95±0.11	10.18±0.01	13.95±0.04	30.07±0.10	200	
Nitrate (mg/L)	.34±0.11	0.45±0.01	2.88±0.30	4.39±0.04	3.88±0.01	3.51±0.01	2.98±0.41	2.16±0.01	2.09±0.01	10	50
Phosphate (mg/L)	0.69±0.20	0.42±0.06	0.55±0.14	5.12±0.01	2.08±0.10	1.89±0.01	0.71±0.30	0.64±0.23	2.84±0.02	50	
Chloride (mg/L)	1.98±0.03	3.97±0.01	3.97±0.11	1.98±0.01	7.94±0.20	4.95±0.02	11.97±0.12	10.94±0.85	5.94±0.01	250	533
COD (mg/L)	1.18±0.10	1.68±0.13	2.00±0.20	1.46±0.01	1.63±0.01	1.69±0.01	1.38±0.05	2.48±0.22	2.03±0.04	10	
BOD (mg/L)	0.94±0.04	1.35±0.01	1.10±0.03	1.18±0.10	1.19±0.04	1.31±0.01	1.35±0.05	1.62±0.03	1.60±0.03	6	

*T-water sample from Tap water; *S- water sample from spring water and *W-water sample from well water

4.3.1 Temperature

Temperature is an important variable in water quality assessment, since it affects physico-chemical and biological processes in water bodies. An increase in temperature changes the physical environment, reduction in oxygen concentration of water bodies. As the water temperature increases the disinfectant demand and by product formation, nitrification, microbial activity, algal growth, taste and odor, lead and copper solubility increase [56]. High temperature enhances the growth microorganism. The mean results of temperature were the minimum level recorded 19.00 ± 0.01 at the site of Goma Ber unprotected ground water and maximum level recording 23.00 ± 0.49 at the site of Abdela meda unprotected spring water and around health center protected ground water. The values reported in this work are within the range recommended by WHO (25-30ºC).

4.3.2 Turbidity

Turbidity is a measure of cloudiness of water. It has no health effects. However, turbidity can interfere with disinfection and provide a medium for microbial growth. High turbidity may indicate the presence of disease-causing organisms [57]. These organisms include bacteria, viruses, and parasites that can cause symptoms such as nausea, cramps, diarrhea, and associated headaches. The mean values of turbidity varied from 4.72 ± 0.02 to 58.7 ± 0.20 NTU. The mean value of S04, S05, S06, W07, W08 and W09 were above the limits of allowed drinking water quality, according to the WHO standard, which is 5 NTU. Turbidity was recorded at highest value due to discharge from municipal domestic waste, coffee waste, soil runoff and particulates in the water.

4.3.3 Total dissolved solid

Water with high TDS is undesirable or harmful for human and aquatic life. Water containing more than 500 mg/L of TDS is not considered as desirable for drinking water supplies. Water containing high solid may cause laxative or constipation effects. Potable water should not contain more than 1000 mg/L of total dissolved solids (TDS) [58]. In the present study, the concentrations of TDS in all sampling sites were ranged from 0.44 ± 0.05 to 3.75 ± 0.04. These values were within the standard limits of drinking water quality set by WHO (500 mg/L) and the variations are significant at $P<0.05$. Thus, a low level of TDS contents of the tap water, spring water, well water and allows the water for drinking and other domestic uses.

4.3.4 Electrical conductivity

The ability of a solution to conduct an electrical current is governed by the migration of solutions and is dependent on the nature and numbers of the ionic species in that solution. Conductivity shows significant correlation with ten parameters such as temperature, pH value, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand, chloride and iron concentration of water. Higher value of EC is a good indicator of the presence of contaminants such as sodium, potassium, chloride or sulfate [59]. In the present study, the concentrations of EC in all sampling sites were ranged from 21.30 ± 0.01 to 243.75 ± 0.56300 µS cm^{-1} (Table 4). The values obtained in all sampling sites were within the standard value of WHO drinking water quality which is 300 µS cm^{-1}. This showed that the EC values of all water samples were within permissible limits and the potable water is safe in terms of EC.

4.3.5 Dissolved oxygen

Dissolved oxygen is one of the most important water quality parameters. Its correlation with water body gives direct and indirect information. For example; bacterial activity, photosynthesis, availability of nutrients, stratification of lakes has relationship with dissolved oxygen [33]. In waters contaminated with fertilizers, suspended material, or petroleum waste, microorganisms such as bacteria will break down the contaminants; hence the oxygen will be consumed and the water will become anaerobic. Typically DO levels less than 2 mg/L will kill fish. DO is an important for many chemical and biological processes taking place in water. Dissolved oxygen in water can decrease due to microbial activity, respiratory and organic decay. Dissolved oxygen value is an indicative of pollution in water and depicts an inverse relationship with water temperature.DO is 4.00 ± 0.01 to 7.16 ± 0.01. This indicates DO with permissible value of 8 mg/L (WHO).

4.3.6 pH

The pH is a measure of the hydrogen ion concentration in water. The pH value of water indicates whether the water is acidic or alkaline. Drinking water with pH between 6.8 to 8.5 is generally considered satisfactory. In this study, the pH ranges from 5.75 to 7.60. The minimum value was recorded at site of Abdela meda unprotected spring water and the maximum value was recorded at site of Yechamo source tap water. Lower values of pH were recorded at S03which could indicate low acidity, which could be as a result of the deposition of acid forming substances in precipitation at that specific sampling site. Therefore, the measured pH values of the drinking water samples were within permissible value of WHO, EU, USEPA and *Ethiopian* (6.5 - 8.5) for drinking water guide lines.

4.3.7 Total hardness

Total hardness of water mainly depends upon the amount of calcium and magnesium salts or both. In the present study the values of total hardness in all sampling sites ranged from 10.0 ± 0.03 to 189.8 ± 0.20 mg/L. The minimum value recorded around technical school unprotected spring water and maximum value recorded at bus station sefer tap water and the variations are significant at $P<0.05$. Water samples were within permissible limit and are safe for drinking and other domestic uses and none of the samples cross the maximum permissible limits of 500 mg/L hardness of WHO [60].

4.3.8 Total alkalinity

Alkalinity of water is defined as the ionic concentration, which can neutralize the hydrogen ions. The range is between 4.95 ± 0.11 to 159.77 ± 0.65 mg/L. The minimum concentration level was recorded at the site Abdela meda unprotected spring water and the maximum concentration level was recorded at bus station sefer tap water. According to WHO the permissible limit for alkalinity in drinking water is 200 mg/L. Therefore, the value of total alkalinity content in all sampling points have been found within the permissible limit of WHO.

4.3.9 Nitrate

Nitrate enters ground or spring water from many sources, including nitrogen-rich geologic deposits, wild-animal wastes, precipitation, septic system drainage, feedlot drainage, dairy and poultry production, municipal and industrial waste, and fertilizer. The minimum concentration level was 0.34 ± 0.11 mg/L recorded at the site Yechamo reservoir tap water and the maximum value was 4.39 ± 0.04 recorded at site around TVET unprotected spring water. All values were found within the recommended value of WHO; which is 50 mg/L; which shows the water is safe in terms of its NO_3^- content for drinking and other domestic uses.

4.3.10 Phosphate

Phosphates are not very toxic to people or other living organisms the main environmental impact associated with phosphate pollution is eutrophication. High levels of phosphorus are quickly consumed by plant and microorganisms, impairing the water by depleting the dissolved oxygen and increasing the turbidities. These impairments will kill or harm fish and other aquatic organisms. The minimum concentration level was 0.42 ± 0.06 mg/L recorded at the site of health center tap water and the maximum value was 5.12 ± 0.01 mg/L recorded around technical school unprotected spring water.

4.3.11 Chloride

Chlorine is normally the most dominant anion in water and it imparts salty taste to the water. The permissible limit of chloride in drinking water is 250 mg/L as given by WHO. In present study, the results of chlorides in all sampling sites were between 1.98 ± 0.01 to 11.97 ± 0.12 mg/L; which is lower thanthe permissible levels of chloride for safe drinking water. Higher chloride concentration is the indicator of sewage pollution and also imparts laxative effect [61]. Atmospheric sources or sea water contamination is reason for bulk of the chloride concentration in groundwater which may exceed due to base-exchange phenomena, high temperature, domestic effluents, septic tanks and low rainfall.

4.3.12 Chemical oxygen demand

COD is related to organic and inorganic pollutants which causes unfavorable conditions for the growth of microorganisms. In present study, the results of COD in all sampling sites were between 1.18 ± 0.01 to 2.03 ± 0.04 mg/L while the permissible limit of (WHO) is 10 mg/L which indicates the water is safe for drinking.

4.3.13 Biological oxygen demand

Biological oxygen demand (BOD) is a measure of the oxygen in the water that is required by the aerobic organisms. The BOD was measured based on the standard method. The mean BOD value of the water samples was within the range of 0.94 ± 0.04 to 1.62 ± 0.03 mg/L; which is below the permissible limit of WHO and EWQG drinking water quality [62].

4.4 Correlation Analysis of physicochemical parameters

pH is strongly correlated with EC and DO, total hardness strongly correlated with DO and pH, TA strongly correlated with total hardness and COD strongly correlated with BOD. The one-way ANOVA result showed that there exist statistically significant differences 95% confidence level in mean concentration of all physic-chemical parameters at $P<0.05$.

4.5 Analysis of heavy metals in water samples

The mean concentration heavy metals (mg/L) in water samples were presented in Table 5.

Table 5: The level of heavy metals concentration (Mean ± SD; n=3) in water samples

Analyte	Water samples									WHO Guide line (2008)	EWQG line (2010)
	T*01	T02	T03	S*04	S05	S06	W*07	W08	W09		
Cu (mg/L)	0.04 ±0.01	0.05±0.02	0.06±0.04	0.07±0.04	0.08±0.06	0.09±0.04	0.10±0.03	0.11±0.09	0.14±0.02	1.0	2
Zn (mg/L)	0.21±0.20	0.36±0.06	0.33±0.03	0.24±0.05	0.26±0.02	0.27±0.03	0.35±0.05	0.24±0.03	0.12±0.01	5	6
Cd (mg/L)	0.06±0.02	0.05±0.00	0.23±0.03	0.15±0.11	0.31±0.01	0.25±0.12	0.33±0.01	0.13±0.23	0.35±0.02	0.005	0.003
Pb (mg/L)	0.26±0.03	0.31±0.14	0.22±0.10	0.23±0.11	0.26±0.01	0.27±0.05	0.28±0.06	0.32±0.01	0.32±0.08	0.01	0.01
Co (mg/L)	0.22±0.01	0.26±0.14	0.30±0.03	0.32±0.02	0.37±0.09	0.39±0.20	0.42±0.03	0.44±0.06	0.50±0.03	0.001	
Cr (mg/L)	0.05±0.02	0.06±0.01	0.07±0.02	0.09±0.01	0.08±0.05	0.14±0.10	0.11±0.02	0.13±0.02	0.16±0.05	0.05	0.05

T*-water sample from Tap water; S*- water sample from spring water and W*-water sample from well water

4.5.1 Copper

Copper occurs naturally in ores. It is mined as a primary ore product from copper sulfide and oxide ores. It is released into the environment through mining, agriculture and industrial activities. Copper is used extensively in the manufacture of textiles electrical conductors, plumbing fixtures, pipes, coins, cooking utensils, wood preservatives, pesticides and fungicides, and copper sulfate fertilizers [63]. The concentration of copper in the water sample under the study ranges from a minimum of 0.05 ± 0.01 mg/L to a maximum of 0.14 ± 0.02 mg/L the concentration of copper was below the recommended limit set by EWQG (2 mg/L) and above the recommended limit set by WHO (1.0 mg/L) guide lines. This shows that the concentration of copper in the water samples was generally low.

4.5.2 Zinc

Zn is one of the important trace elements that play a vital role in the physiological a metabolic process of many organisms. It is an essential trace element for bacteria, plants and animals including humans. It also plays an important role in protein synthesis and is a metal, which show low concentration in surface water due to its restricted mobility from the place of rock weathering or from natural source [64]. The measured concentration of zinc in the study site was ranging from 0.12 ± 0.01 mg/L to 0.36 ± 0.06 mg/L. The concentrations recorded were higher than WHO (0.2 mg/L) permissible level, but lower than the EWQG (5.0 mg/L) guideline.

4.5.3 Cadmium

Cadmium is highly toxic non-essential heavy metal and it does not have a role in biological process in living organisms. Thus, even in low concentration, cadmium could be harmful to living organisms [65]. Natural as well as anthropogenic sources of cadmium, including industrial emissions and the application of fertilizer and sewage sludge may lead to contamination of water, grown for human consumption [66]. The mean concentration of Cd content in water samples was ranging from 0.05 ± 0.00 mg/L to 0.35 ± 0.02 mg/L. Except T02 others values obtained were found to be extremely higher than the permissible limit of 0.005 mg/L set by WHO.

4.5.4 Lead

The values of lead ranging from 0.22 ± 0.10 mg/L to 0.32 ± 0.08 mg/L in all the entire selected sites, the values recorded were above the maximum permissible limit of EWQG and WHO (0.01 mg/L). This could pose detrimental effect to human being; hence appropriate measure has to be taken to minimize the possible effects of lead in the water samples of the study site.

4.5.5 Cobalt

Cobalt concentration ranges from 0.22 ± 0.01 mg/L to 0.50 ± 0.03 mg/L in water samples. Concentrations of cobalt was above the recommended limit at all sampling sites. The permissible limit is 0.001 mg/L (WHO). Cobalt has been found in a variety of media, including air, surface water, leachate from hazardous waste sites, groundwater, soil, and sediment [63]. This could pose detrimental effect to human being; hence appropriate measure has to be taken to minimize the possible effects of cobalt in the water samples of the study site.

4.5.6 Chromium

Chromium concentration ranges from 0.05 ± 0.02 to 0.16 ± 0.05 mg/L. All value obtained above the permissible limit of 0.02 mg/L (WHO). Chromium and its compounds can be discharged into drinking water through erosion, atmospheric precipitation, geochemical source and effluents. This could pose detrimental effect to human being; hence appropriate measure has to be taken to minimize the possible effects of chromium in the water samples of the study site.

4.5.7 Correlation Analysis

Copper is strongly correlated with Co, Cr and strongly negatively correlated with Zn, Cd and Pb. Zinc is weakly correlated with Cd and Pb. Cadmium is strongly correlated with Pb. Lead is weakly negatively with Co. Cobalt strongly correlated with Cr. Chromium strongly correlated with Cu, Co and weekly correlated with Zn.

4.5.8 The mean variation of selected heavy metals by using one-way ANOVA

The analysis one-way ANOVA (Table 5 of the appendix) showed that there exist statistically significant differences 95% confidence level in mean concentration between Cu, Zn, Cd, Pb, Co and Cr at $P<0.05$.

4.6 Bacteriological water quality of the study sites

The average Most Probable Number count of the samples ranged from 4 to 86/100 mL for Total coliform and 0 to 30/100 mL for Fecal coliform. Coliform bacteria are present in the environment and feces of all warm-blooded animals and humans. However, their presence in drinking water indicates that disease-causing organisms (pathogens) could be in the water system. Most pathogens that can contaminate water supplies come from the feces of humans or animals. Testing drinking water for all possible pathogens is complex, time-consuming, and expensive. It is easy and inexpensive to test for coliform bacteria. If testing detects coliform bacteria in a water sample, water systems search for the source of contamination and restore safe drinking water. Membrane filtration method was used to determine the degree of contamination (total coliforms and fecal coliforms) of drinking water samples. MF and colony count techniques assume that each bacterium, clump of bacteria, or particle with bacteria attached, will give rise to a single visible colony. Each of these clumps or particles expressed as colony forming units per unit volume. Coliform bacteria, thermotolerant (fecal) coliforms and *E. coli* have, for almost a century, been used as indicators of the bacterial safety of drinking-water [67]. Total coliforms and fecal coliforms analysis using colony counting of the water samples is presented in Table 6.

Table 6: The values of Bacteriological test for the analyzed water samples.

Types of coliforms	T*-01	T-02	T-03	S*-04	S-05	S-06	W*-07	W08	W-09	WHO guide line (2008)
Total coliforms (CFU/100 mL)	52	64	65	10	6	4	86	52	16	0
Fecal coliforms (CFU/100 mL)	10	12	30	12	0	0	0	14	22	0

T*-water sample from Tap water; S*- water sample from spring water and W*-water sample from well water

4.6.1 Total coliforms

The presence of total coliforms may or may not indicate fecal contamination. In extreme cases, a high count for the total coliform group may be associated with a low, or even zero, count for fecal coliforms. Such a result would not necessarily indicate the presence of fecal contamination. It might be caused by entry of soil or organic matter into the water or by conditions suitable for the growth of other types of coliform. The minimum coliforms are at Abdela meda unprotected spring water and maximum is around health center protected total ground water 66 cfu/100 mL. This could be because of different anthropogenic activities and organic matter into water.

4.6.2 Fecal coliforms

A group of bacteria commonly referred as fecal coliforms act as an indicator for fecal contamination of water. The presence of very few fecal coliform bacteria or absence (zero) would indicate that water probably contains no disease-causing organisms, while the presence of large numbers of fecal coliform bacteria would indicate a very high probability that the water could contain disease-producing organisms making the water unsafe for consumption. The absence (Zero) of fecal coliform at S05, S06, and W07 could be less contamination by pathogenic organisms while the maximum at G-09 (Goma Ber unprotected ground water) could be more contamination by pathogenic organisms. This finding also consistent with the previous studies conducted in the Jimma zone on spring water and hand dug well bacterial loads of non-chlorinated water sources [68].

5. CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSION

In this study physico-chemical parameters such as Temperature, Turbidity, TDS, EC, DO, pH, total hardness, total alkalinity, NO_3^-, PO_4^{3-}, Cl^- , BOD, COD, heavy metals (Cu, Zn, Cd , Pb , Co and Cr) and bacteriological test (Total coliforms and Fecal coliforms) of the tap water, spring water and well water were investigated. From the finding, physico-chemical parameters such as Temperature, DO, pH, TDS, EC, total hardness, total alkalinity, NO_3^-, PO_4^{3-}, Cl^-, BOD, COD, heavy metals such as Cd (T02), Cu , Zn and Fecal coliforms of (S05, S06 and W07) were found within the recommended value of EWQG and WHO guide line for drinking water quality. However, Turbidity for spring and well water, and pH for S06, concentration of Cd, Pb, Co and Cr for tap, spring and well water), and all total coliforms and Fecal coliforms for T01, T02, T03, S04, W08 and W09 were above the recommended value of EWQG and WHO guide line for drinking water quality. Based on the finding of this study, some of the water samples for some parameters were above the EWQG and WHO guideline for drinking water.

5.2. RECOMMENDATIONS

Based on the finding of this study, the following recommendations are forwarded.

- The government and other responsible authorities have to give appropriate attention for the improvement of the water quality of the study site.
- Further studies have to be conducted to know the source of common pollutants of the water source and to suggest possible scientific solution for the community of the study site.

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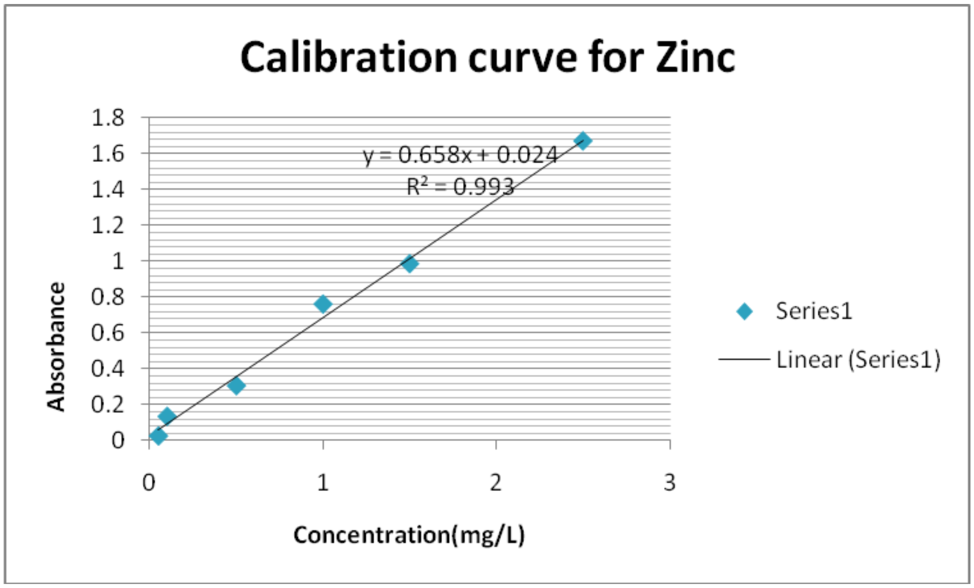
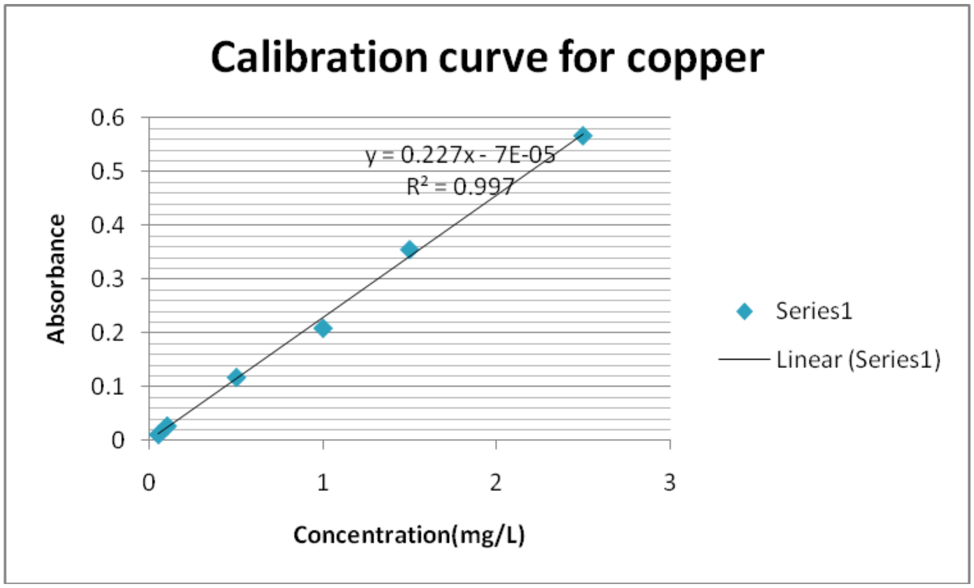
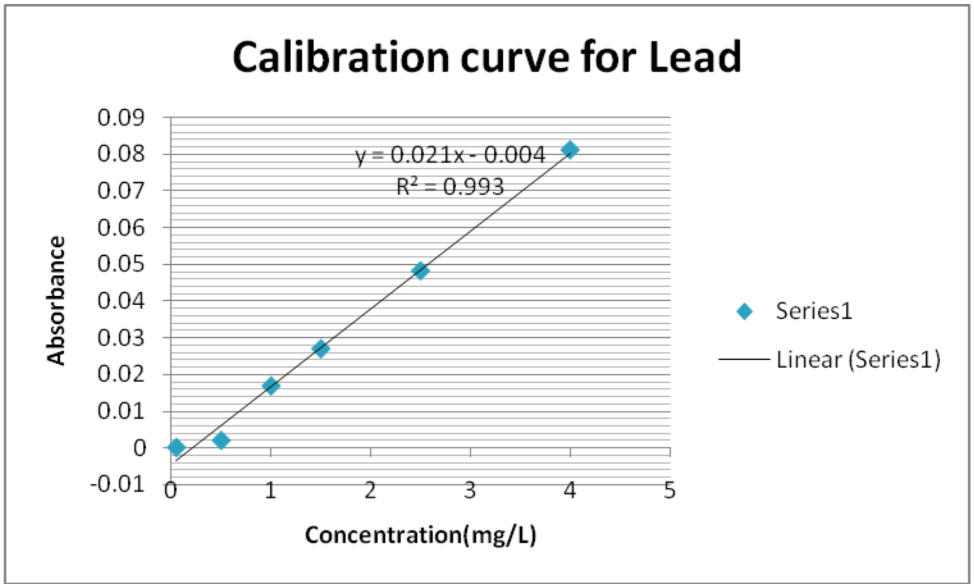
APPENDIX

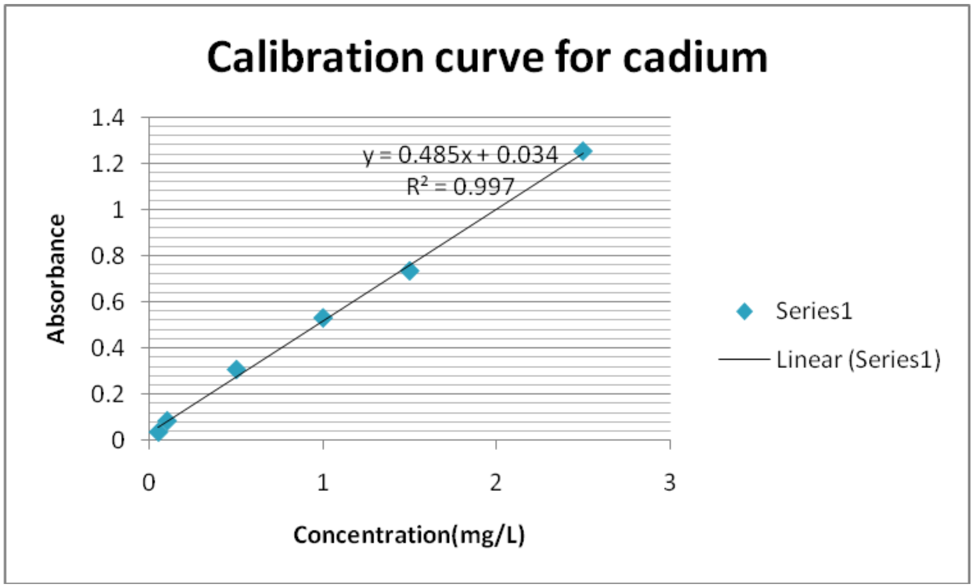
Table 1: Concentrations of working standard solutions for GFAAS instrument calibration and correlation coefficients of the calibration curves.

Metal	Concentration of intermediate standard solution (mg/L)	Concentration of working standard solutions (mg/L)	Linear Range (mg/L)	Regression equation	Correlation coefficient (R^2)
Cu	20	0.05, 0.66, 1.26, 1.89, 2.50	0.05-2.50	Y=0.2275x+0.0007	0.9975
Zn	20	0.05, 0.66, 1.26, 1.89, 2.50	0.05-2.50	Y=0.6589x+0.0244	0.9938
Cd	20	0.05, 0.66, 1.26, 1.89, 2.50	0.05-2.50	Y=0.485x + 0.0341	0.9978
Pb	20	0.05, 0.66, 1.26, 1.89, 2.50	0.05-2.50	Y=0.0212x+0.0046	0.9937
Co	20	0.05, 0.66, 1.26, 1.89, 2.50	0.05-2.50	Y=0.0562x + 0.003	0.9957
Cr	20	0.05, 0.66, 1.26, 1.89, 2.50	0.05-2.50	Y=0.0563x + 0.003	0.9985

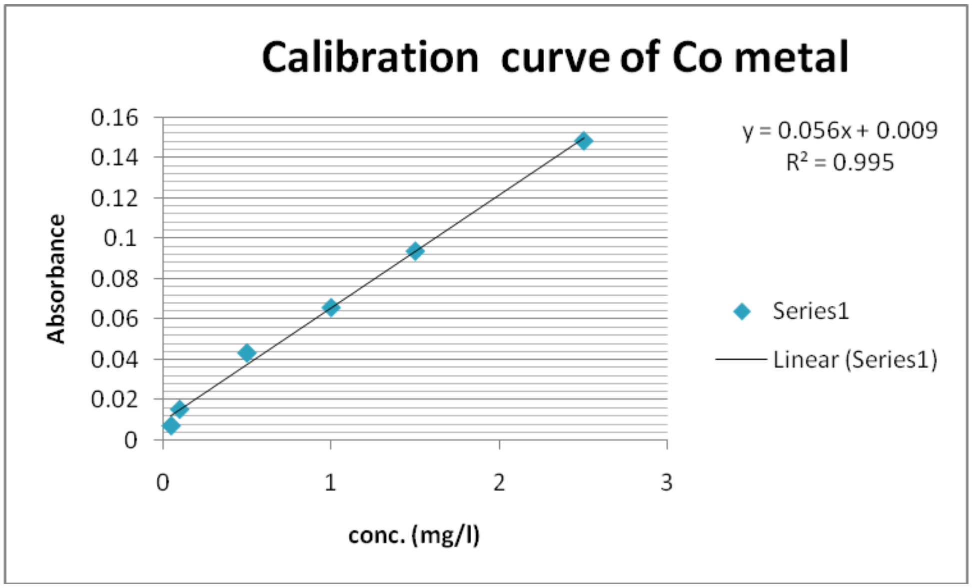



Calibration curve for copper
0.6
0.5
0.4
0.3
0.2
0.1
0
Absorbance
y = 0.227x - 7E-05
R² = 0.997
0
1
2
3
Concentration(mg/L)
◆ Series1
Linear (Series1)


Calibration curve for Lead
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
Absorbance
y = 0.021x - 0.004
R² = 0.993
0
1
2
3
4
5
Concentration(mg/L)
◆ Series1
Linear (Series1)



Calibration curve for cadium
y = 0.485x + 0.034
R² = 0.997
Absorbance
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
Concentration(mg/L)
Series1
Linear (Series1)



Calibration curve of Co metal
y = 0.056x + 0.009
R² = 0.995
Absorbance
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
1
2
3
conc. (mg/l)
Series1
Linear (Series1)

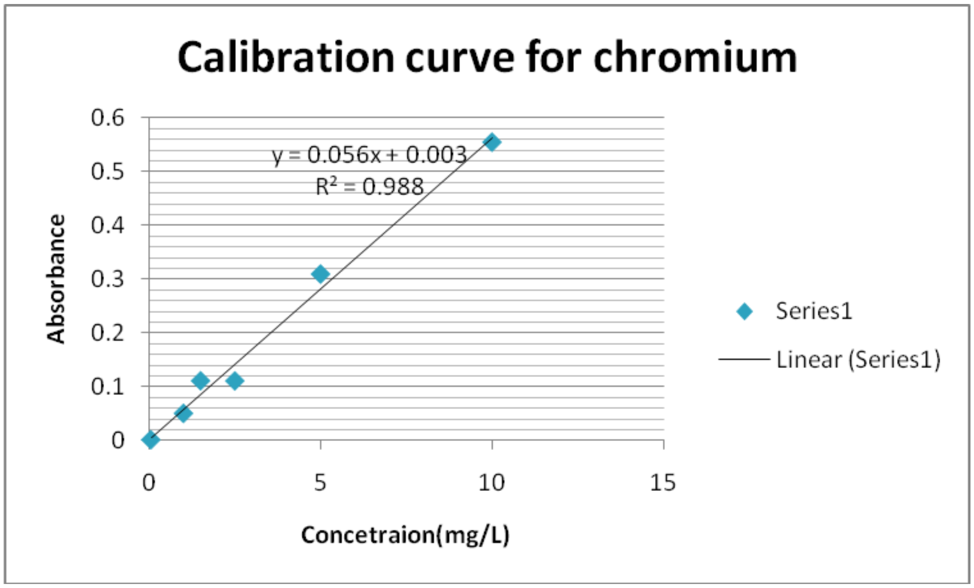

Calibration curve for chromium
y = 0.056x + 0.003
R² = 0.988
Absorbance
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
Concetraion(mg/L)
Series1
Linear (Series1)

Table 2: Pearson correlation coefficient among physicochemical parameters of Yebu different water source samples

M	T^o	Tur	TDS	EC	DO	pH	TH	TA	NO_3^-	PO_4^{3-}	Cl^-	BOD	COD
T^o	1												
Tur	-.753*	1											
TDS	.590	-.481	1										
EC	.124	-.357	-.197	1									
DO	-.379	.341	-.578	.742*	1								
pH	.006	.012	-.289	.838**	.850**	1							
TH	-.257	.377	-.454	.679*	.932**	.800**	1						
TA	-.028	.342	-.251	.460	.659	.610	.851**	1					
NO_3^-	-.372	.198	.164	-.683*	-.562	-.558	-.711*	-.690*	1				
PO_4^{-3}	.175	-.249	.147	-.487	-.676*	-.399	-.736*	-.525	.625	1			
Cl^-	-.362	-.016	-.148	.013	.068	-.225	-.141	-.568	.177	-.342	1		
BOD	-.388	.434	.027	-.506	-.228	-.491	-.106	.057	.198	.085	-.050	1	
COD	-.347	.433	.033	-.535	-.256	-.511	-.118	.079	.183	.102	-.100	.997**	1

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

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

Table 3: ANOVA between and within physic-chemical parameters of different source of water samples at 95% confidence level.

ANOVA

Physico-Chemical	Source of variation	Sum of squares	Degree of freedom	Mean square	$F_{calculated}$	P-value
Temperature	Between samples	41.869	8	5.234	187.723	.000
	Within samples	.502	18	.028		
	Total	42.371	26			
Turbidity	Between samples	7163.361	8	895.420	1962892.857	.000
	Within samples	.008	18	.000		
	Total	7163.369	26			
TDS	Between samples	24.702	8	3.088	1300.367	.000
	Within samples	.043	18	.002		
	Total	24.744	26			
EC	Between samples	227823.829	8	28477.979	188650.724	.000
	Within samples	2.717	18	.151		
	Total	227826.546	26			
DO	Between samples	38.879	8	4.860	784.120	.000
	Within samples	.112	18	.006		
	Total	38.990	26			
pH	Between samples	10.823	8	1.353	281.676	.000
	Within samples	.086	18	.005		
	Total	10.910	26			
TH	Between samples	158593.657	8	19824.207	210471.326	.000
	Within samples	1.695	18	.094		
	Total	158595.352	26			
TA	Between samples	115349.954	8	14418.744	55728.548	.000
	Within samples	4.657	18	.259		
	Total	115354.6	26			

		11				
NO_3^-	Between samples	47.972	8	5.997	120310.571	.000
	Within samples	.001	18	.000		
	Total	47.973	26			
PO_4^{3-}	Between samples	57.633	8	7.204	67417.361	.000
	Within samples	.002	18	.000		
	Total	57.635	26			
Cl^-	Between samples	317.239	8	39.655	446.327	.000
	Within samples	1.599	18	.089		
	Total	318.838	26			
BOD	Between samples	1.218	8	.152	374.872	.000
	Within samples	.007	18	.000		
	Total	1.225	26			
COD	Between samples	1.887	8	.236	607.385	.000
	Within samples	.007	18	.000		
	Total	1.894	26			

Table 4: Pearson correlation coefficient among metals in Yebu different water source

	Cu	Zn	Cd	Pb	Co	Cr
Cu	1					
Zn	-.569**	1				
Cd	-.508**	.103	1			
Pb	-.508**	.103	1.000**	1		
Co	.980**	-.483*	-.486*	-.486*	1	
Cr	.732**	-.471*	-.142	-.142	.745**	1

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

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

Table 5: One-way ANOVA between and within selected heavy metals in different water sources of samples at 95% confidence level.

ANOVA						
		Sum of Squares	Df	Mean Square	$F_{calculated}$	P-value
Cu	Between samples	.026	8	.003	112.851	.000
	Within samples	.001	18	.000		
	Total	.026	26			
Zn	Between samples	.249	8	.031	76.569	.000
	Within samples	.007	18	.000		
	Total	.256	26			
Cd	Between samples	.000	8	.000	3.169	.020
	Within samples	.000	18	.000		
	Total	.000	26			
Pb	Between samples	.000	8	.000	3.159	.020
	Within samples	.000	18	.000		
	Total	.000	26			
Co	Between samples	.201	8	.025	789.136	.000
	Within samples	.001	18	.000		
	Total	.201	26			
Cr	Between samples	.052	8	.006	17.793	.000
	Within samples	.006	17	.000		
	Total	.058	25			